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The relationship between maximal isometric and isotonic neck strength of hockey players and wrestlers

Broennle, Morgan

The Relationship Between Maximal Isometric and Isotonic Neck Strength of Hockey Players and Wrestlers

By

Morgan Broennle

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Abstract

The purpose of this study was first to examine the relation between maximal isometric neck force and predicted 1-RM cervical strength values, for neck flexion and extension. The second purpose was to compare maximal isometric and predicted 1-RM neck strength values between hockey players and wrestlers. Athletes were recruited from the Lakehead University varsity hockey and wrestling teams and from the Thunder Bay North Stars, with a group of Lakehead University kinesiology students serving as a control group. Each group consisted of eight participants, all male between the ages of eighteen and twenty-four. Anthropometric measurements, including height, mass, neck length, and neck girth were taken prior to testing. Isometric and isotonic cervical strength testing was completed using a modified Nautilus neck strengthening machine. A 6-RM submaximal test was completed for cervical flexion and extension, from which 1-RM values were predicted using the Wathen (1994) equation. Maximal isometric neck flexion and extension strength were measured using a load cell attached to the arm of the Nautilus machine, which was set in a neutral neck position. Results of the Pearson Moment Correlation indicated that a stronger relation exists between flexion and extension strength measurements of the same contraction type ($r_{isotonic} = 0.83$; $r_{isometric} = 0.81$, $p < 0.01$) than between cervical force values of the same movement direction ($r_{extension} = 0.47$; $r_{flexion} = 0.45$, $p < 0.05$). These results suggest that cervical strength measurements are specific to the mode of testing and therefore support the previous literature, which recommends that the conditions used for assessing muscular performance be specific to the training modality. A 3x2x2 mixed factorial ANOVA showed that the mean normalized isotonic neck force of the wrestlers was significantly greater than that of the hockey players, for both flexion and extension. In terms of normalized isometric neck force, there was no significant difference between the mean value of

the wrestlers and the hockey players. As no other significant differences were found between these groups of athletes, contrasts in isometric and isotonic neck strength are likely associated with the demands of each athlete's respective sport and their sport specific strength training.

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CHAPTER ONE-INTRODUCTION

Throughout the literature it is recommended that athletes involved in contact sport include strengthening exercises for the cervical musculature within their training programs in order to reduce the risk and severity of neck injuries and improve sport performance (Cross & Serenelli, 2003; Tator, Carson, & Cushman, 2000; Tator & Edmonds, 1984; Wroble & Albright, 1986). Resistance training of the cervical spine can enhance an athlete's ability to effectively stabilize the neck, while developing reflex systems and proprioceptive awareness, all factors that contribute to injury prevention and improved body mechanics. Additionally, an increase in the contractile forces of the neck can improve the ability of the neck muscles to absorb external forces. According to Cross and Serenelli (2003) an appropriate cervical strength training program for any athlete involved in contact sport should begin with isometric exercise and progress to include isotonic workouts. Although conventional resistance exercises and isometric training are beneficial to improving intrinsic muscle strength and cervical stability, researchers found that neck specific, isotonic exercises are necessary for developing neck muscle size, strength, and functional capabilities related to contact sport (Conley, Stone, Nimmons, & Dudley, 1997; Cross & Serenelli, 2003; Leggert et al., 1991; Ylinen et al., 2009).

In order to monitor the effectiveness of a cervical training program regular assessment of cervical muscle strength should be completed (Kraemer, Ratamess, Fry, & French, 2006). The protocol used for assessing muscular performance, however, should be specific to the training modality (Kraemer, Ratamess, Fry, & French, 2006). Although isometric testing is useful for evaluating neck strength during the initial stages of a sports training program, an isotonic testing method should be used for assessing neck strength during later stages of conditioning.

In comparison to isometric and isokinetic cervical muscle assessment, the literature is limited in regards to isotonic cervical strength testing. This void may be due to the heightened vulnerability of the cervical neck and the increased risk of injury associated with isotonic exercise and strength testing. However, with proper precautions researchers have safely employed isotonic strength testing modalities from which they have acquired a greater understanding of cervical muscle function (Burnnett, Colemann, Netto, 2008; Conley, Stone, Nimmons, & Dudley, 1997). Unfortunately, researchers that investigated isotonic neck muscle functioning used extensive laboratory equipment, such as electromyography (EMG) or magnetic resonance imaging (MRI), which is not easily accessible or affordable to athletes or sport teams. Additional studies that examined the training effects of the cervical muscles in response to dynamic exercises used isometric testing techniques. Therefore, results from these studies are questionable and limited in application, as the testing techniques do not match the training modalities. A more accessible method for isotonic neck muscle assessment is required in order for equipment and test data to be applicable to athletes, coaches and athletic trainers.

A predictive 1-RM neck test may be an effective method for assessing athletes' isotonic neck strength and monitoring isotonic cervical training. No research, however, has measured the absolute 1-RM or predicted 1-RM values for any neck movement. Although researchers have developed numerous isometric tests for assessing neck strength, no study has examined the relation between maximal isometric and predicted 1-RM measures of neck strength. Correlations between isometric and isotonic strength values would confirm whether specific measures of muscle function are required, or if various muscle capabilities can be generalized from a single cervical strength test. Additionally, no study was found that compared the cervical neck strength profiles of various athletes. Such research would provide valuable insight into the training effects of the cervical muscles and assist coaches and trainers in prescribing appropriate neck training programs for athletes. Therefore, the aim of this study was to: 1) examine the relation between maximal isometric neck force and predicted 1-RM cervical strength values, for neck flexion and extension; 2) compare the maximal isometric with the predicted 1-RM (isotonic) neck strength values among hockey players, wrestlers, and controls. Hockey players and wrestlers were included for cervical strength testing as both athletes play a contact sport in which specific trends in neck injuries have been observed. Furthermore, there is a considerable difference in the cervical strength training that is commonly followed by each type of athlete.

CHAPTER TWO-REVIEW OF LITERATURE

Overview

This section is a review of the relevant literature related to cervical muscle strength and functioning. First the anatomy and function of the cervical spine is reviewed. The benefits of cervical strength training to athletes in contact sport are then discussed followed by an explanation as to why cervical strength testing should accompany such training. Finally, as the current methods of cervical strength testing are discussed the need for further research is highlighted.

The Cervical Spine: Anatomy and Function

The cervical spine is a unique structure in that it has numerous conflicting roles. It is rigid enough to support the skull, protect the spinal cord and vascular structures, and provide sites for muscular attachment (Roy & Irvin, 1983). It also has enough flexibility to permit an extensive range of head movement while integrating the head with the body and the environment (Shapiro & Frankel, 1989). Intervertebral discs located between cervical vertebrae act as shock absorbers to protect the spine and the brain. Finally, the spine provides portals of entry, exit, and passage for neurovascular structures (Shapiro & Frankel, 1989). In order for the cervical spine to achieve this diversity of roles, numerous structures are required. As Shapiro and Frankel (1989) explained, knowledge regarding these various cervical structures and their interrelationships is essential for understanding mechanisms specific to the cervical spine. Anderson, Hall, and Martin (2005) provided an effective anatomical description of the cervical spine to aid in the understanding of cervical spine functioning.

As Anderson, Hall, and Martin (2005) described the cervical spine is the most proximal section of the vertebral column, composed of seven vertebrae. The third to seventh vertebrae (C3 to C7) are typical vertebrae, similar in structure and function to each other, and to the vertebrae of the thoracic and lumbar region (Anderson, Hall, & Martin, 2005). In a typical cervical vertebra the anterior components include the vertebral body, intervertebral disc, pedicles, and all attached ligaments (Figure 2.1). The vertebral foramen, lamina, spinous process, and accompanying ligaments constitute the posterior components (Figure 2.1).

Each typical cervical vertebra has a total of seven bony processes, each having a specific function. At the point where each lamina and pedicle joins, a transverse process extends laterally from the vertebra (Tortora, 2002). A single spinous process projects posteriorly from the junction of the two laminae (Figure 2.1). The spinous and transverse processes serve as sites for muscle attachments. Figure 2.2 displays the spinous and transverse processes, as they appear when the cervical vertebrae are stacked to form the cervical spine. The characteristic lordotic curve of the cervical spine is also portrayed. The remaining processes are important in providing protective passageways for neural and vascular structures. The two inferior articular processes of a vertebra connect with the two superior articular processes of the adjacent, inferior vertebra to form the facet joints (Figure 2.3) (Tortora, 2002). The superior and inferior borders of the right and left pedicles contain notches. By connecting with the pedicles of the successive vertebra these notches provide openings called intervertebral foramina, through which the spinal nerves pass (Anderson et al., 2005). As the vertebrae form a stacked column the vertebral arches, posterior sides of the vertebral bodies, and intervertebral discs form a protective passageway for the spinal cord and associated blood vessels (Figure 2.3) (Anderson et al., 2005). Additionally, each cervical vertebra has two transverse foramina, through which the vertebral artery and its accompanying vein and nerve fibers pass.

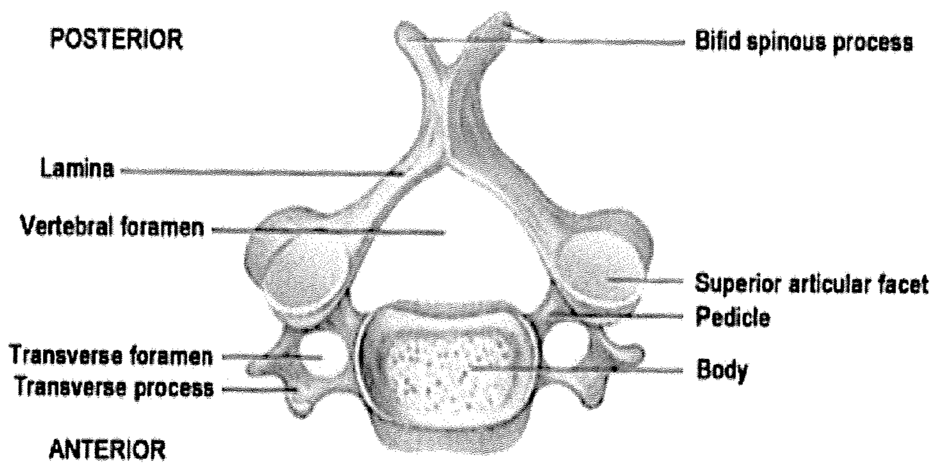


Figure 2.1. Superior view of a typical cervical vertebra. *Note.* Adapted from *Principles of Human Anatomy,* p. 161, by G.J. Tortora, 2002, New York: John Wiley & Sons

Figure 2.4 demonstrates the intervertebral discs that are located between each typical vertebra. These fibrocartilaginous discs provide cushioning between the articulating vertebral bodies and contribute to the flexibility of the cervical spine (Anderson, Hall, & Martin, 2005). In the intervertebral disc, a thick ring of fibrous cartilage, the annulus fibrous, surrounds a gelatinous material known as the nucleus pulposus (Figure 2.4). This material enables the discs to act as shock absorbers and allows the spine to bend (Anderson et al., 2005).

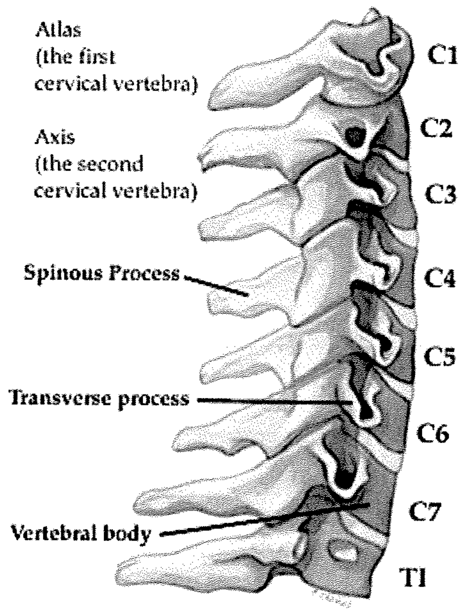


Figure 2.2. Lateral view of the cervical spine, featuring the spinous and transverse processes of the cervical vertebrae. *Note.* Adapted from Parker, n.d.

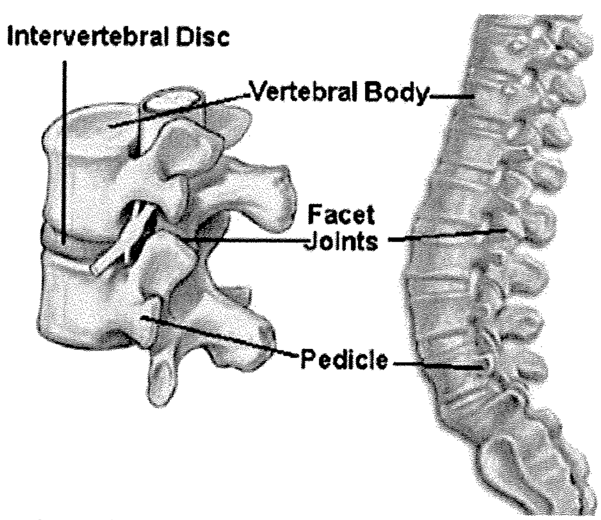


Figure 2.3. Posterolateral view of stacked vertebrae. The components of the cervical vertebrae function to provide protective passageways for the spinal cord, nerves, and blood vessels. *Note.* Adapted from Bridwell, n.d.

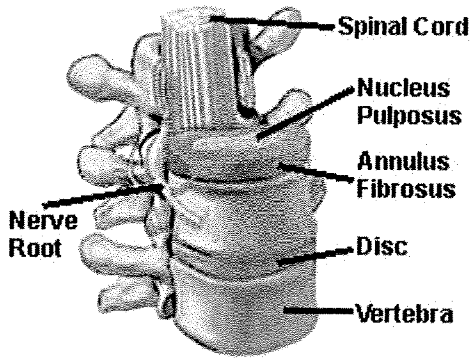


Figure 2.4. Structure and location of intervertebral discs. *Note*. Adapted from Sasso and Traynelis, n.d.

Tortora (2002) provided a detailed explanation of the first two cervical vertebrae. C1 (the atlas) and C2 (the axis) are atypical vertebrae and differ considerably from the other vertebrae in structure and function. The first cervical vertebra, the atlas, supports the head and articulates with the skull. The atlas is a ring of bone with anterior and posterior arches and large lateral masses. Unlike the other vertebrae it lacks a body and spiny process (Figure 2.5). The superior surfaces of the lateral masses, called superior articular facets, are concave and articulate with the occipital condyles of the occipital bone to form the atlanto-occipital joints. These articulations permit the movement seen when moving the head to signify yes. The inferior surfaces of the lateral masses, the inferior articular facets, articulate with the second cervical vertebra. The second cervical vertebra, the axis, has a body and process known as the dens (Figure 2.5). The dens makes a pivot on which the atlas and head rotate, as in moving the head to signify no. This arrangement also permits side-to-side rotation of the head (Tortora, 2002).

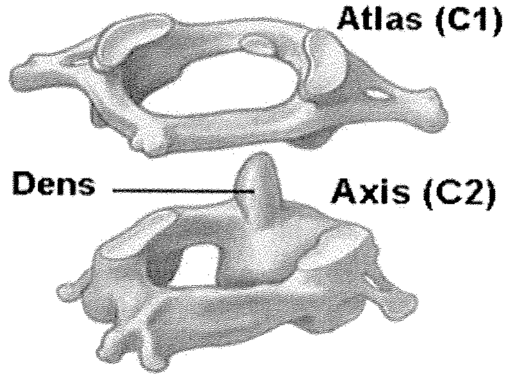


Figure 2.5. Atypical cervical vertebrae. *Note*. From Bridwell, n.d.

The ligaments comprise the primary stabilizing component of the cervical spine, preventing excessive movement that could cause injury (Proctor & Cantu, 2000). The stability function of the cervical ligaments is largely due to their composition, consisting mainly of elastin and collagen. The elastin fibers are arranged longitudinally, which allows the ligaments to stretch up to twice their length and return to their original size (Proctor & Cantu, 2000). The anterior and posterior longitudinal ligaments connect the vertebral bodies of motion segments in the cervical spine (Anderson, Hall, & Martin, 2005). The supraspinous ligament attaches the spinous processes throughout the length of the spine and is enlarged in the cervical region, where it is known as the ligamentum nuchae. The ligamentum nuchae separates the muscles of the posterior portion of the neck at the midline (Roy & Irvin, 1983). Another major ligament, the ligamentum flavum, connects the pedicles of adjacent vertebrae (Anderson et al., 2005). This ligament contains a high proportion of elastic fibers that keep it constantly in tension, contributing to spinal stability. Other posterior ligaments include the capsular ligaments, interspinous ligaments, and intertransverse ligaments, all of which contribute to further stability and support within the cervical spine (Proctor & Cantu, 2000). Figure 2.6 displays the major ligaments of the cervical spine.

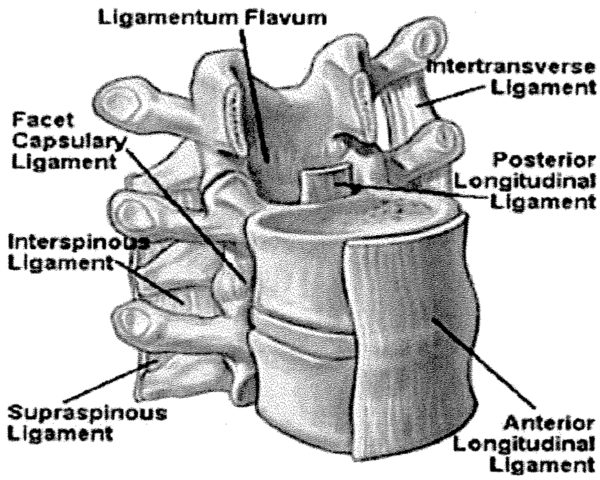


Figure 2.6. Major ligaments of the cervical spine. *Note*. From Bridwell, n.d

According to Tortora (2002) the muscles that move the head and neck are quite complex as they have multiple origins and insertions and there is considerable overlap among them. Nevertheless, the cervical muscles interact to provide spinal balance and stability, while enabling movement (Roy & Irvin, 1983). The major muscles of the cervical spine include the longissimus cervicis, longissimus capitis, splenius capitis, splenius cervicis, trapezius, levator scapulae, and the sternocleidomastoid muscle (Roy & Irvin, 1983). Acting together both longissimus capitis muscles extend the head, but rotate the head when acting singly. The longissimus cervicis muscles extend the cervical portion of the vertebral column when acting together and lateral flex the same region when acting singly. Contraction of the two sternocleidomastoid muscles together flexes the cervical portion of the vertebral column and extends the head (Tortora, 2002). Acting singly, the sternocleidomastoid muscle laterally flexes and rotates the head. The two splenius muscles are bandage-like muscles that are attached to the sides and back of the neck. They extend the head and laterally flex and rotate the head (Tortora, 2002). Although the trapezius and levator scapulae muscles act primarily to move the shoulder, they both extend over the posterior neck region and assist in head extension and stabilization of the cervical spine (Figure 2.7). Muscles in the head and neck region contract and relax in response to nerve impulses originating in the brain. Injury to the cervical spine occurs, however, when external forces flex, extend, rotate or compress the spine past its normal range of motion (Proctor & Cantu, 2000).

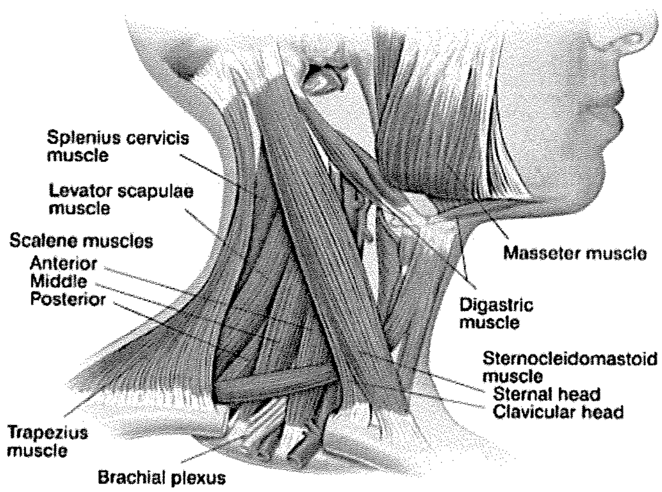


Figure 2.7. Anterolateral view of the neck, displaying several of the cervical muscles that assist in head and neck movement. *Note.* Adapted from Gill, 2009

Resistance Training for the Cervical Spine

The literature suggests that it is beneficial for athletes involved in contact sport to include resistance training of the cervical muscles within their conditioning programs (Cooper, McGee, & Anderson, 2003; Cross & Serenelli, 2003; Tator, Carson, & Cushman, 2000; Tator & Edmonds, 1984). Resistance training may reduce the risk and severity of neck injuries that are commonly associated with contact sports, while assisting athletes in maintaining proper posture and body mechanics (Cross & Serenelli, 2003). Resistance training enables the cervical muscles to contract faster with increased force by enhancing neural stimulation and increasing muscle cross-sectional area (Gandevia, 2001). Increased muscle size and strength may improve the ability of the cervical muscles to absorb energy during head impact while improving spinal stability (Du Toit, Buys, Venter, & Olivier, 2003; Roy & Irvin, 1983). Additionally resistance training can enhance reflex systems and develop proprioception of the cervical spine, factors that contribute to injury prevention and improved posture and performance (Falla & Farina, 2008).

Cross and Serenelli (2003), provided a three phase training program aimed specifically at strengthening the cervical muscles of athletes in contact sport. The first phase emphasizes isometric exercises, which strengthen the intrinsic neck muscles and improve cervical stability (Cross & Serenelli, 2003). The second stage of development incorporates dynamic, rhythmic, and transitional stabilization of the cervical spine (Cross & Serenelli, 2003). In this stage, the athlete progresses through various movements while keeping their head and neck within a functional range. During the third phase of the program the athlete advances to complex movement patterns and exercises that target the larger, extrinsic muscles of the neck. Unlike intrinsic muscles that respond favourably to isometric exercise, research has shown that larger muscle groups, such as the trapezius and levator scapulae, respond best to isotonic activity (Cross & Serenelli, 2003). Therefore, the final phase of a cervical strength training program should focus on isotonic exercises. Various weight machines and/or free weights may be used that enable the neck muscles to move in a full range of motion against an external resistance. Isotonic neck exercises are especially valuable to athletes in contact sport as it incorporates cervical stabilization with dynamic movement so that cervical muscle activity is comparable to that required during sports play.

Kraemer, Ratamess, Fry, and French (2006) explained that regular assessment of muscular strength is essential to obtaining training goals when following any type of resistance training program. Monitoring strength performance throughout a training program enables proper evaluation of the exercise prescription and allows for appropriate modifications to be made. The protocol used for assessing muscular performance, however, should be specific to the training modality (Kraemer, Ratamess, Fry, & French, 2006). Although isometric testing is useful for evaluating neck strength during the initial stages of a cervical training program, an isotonic testing method should be used for assessing neck strength during later stages of conditioning. As will be discussed in the following section, however, there is a lack of appropriate isotonic testing techniques for evaluating dynamic cervical muscle performance.

Methods for Testing Neck Strength

Dvir and Prushansky (2008) recently completed an extensive literature review that focused on cervical muscle strength testing. The authors discussed various methods that have been used for assessing neck muscle strength and the clinical applications of each procedure. As with resistance training, strength testing of the neck musculature involves isometric, isokinetic or isotonic techniques based on the extent of dynamic movement involved, or the lack thereof. Although the majority of neck testing studies have favoured isometric techniques, the variations in equipment and procedures have resulted in a vast range of cervical strength scores. Additionally, the lack of research involving isotonic testing techniques suggests that the literature regarding cervical muscle strength and functioning is less than complete.

Isometric neck testing techniques.

According to Dvir and Prushansky (2008), isometric techniques are most frequently used for testing cervical muscle strength. Isometric techniques require an individual to push or pull maximally against a resistance, using a specific muscle group(s), without any movement about the joint. During isometric muscle action the muscle length does not change because the contractile force is equal to the resistive force (Harman, 2000). Isometric measurements, therefore, represent cervical muscle functioning in a static position. There are several advantages of using static measurements to assess cervical muscle strength including a low risk of injury, relatively simplistic instrumentation, and straightforward methodology (Dvir & Prushansky, 2008). For these reasons, researchers have employed isometric procedures, evaluations, and assessment tools for cervical muscle testing. Isometric testing most commonly involves either manual muscle assessment (MMT), handheld dynamometry, or fixed frame dynamometry. Additionally, De Koning et al. (2008) identified the endurance test of short neck flexors as a common isometric testing technique.

The muscle endurance test of short neck flexors was first described by Grimmer (1994), but several modified methods have since been used. The test involves positioning the participant in a supine, hook-lying position, with the chin tucked into the chest. While maintaining this "chin-tuck" position the participant is required to lift the head and neck until the head is approximately 2.5 cm above the table and to hold this position for as long as possible (Figure 2.8). The time that a participant can maintain this position is reflective of his or her neck flexor muscle endurance.

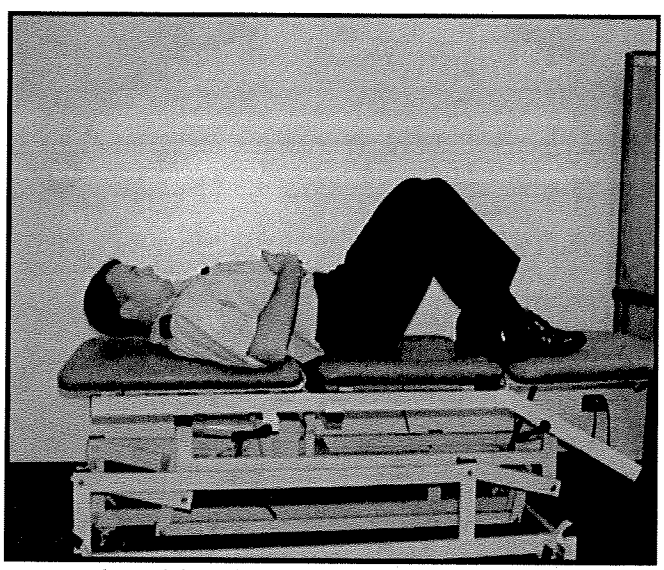


Figure 2.8. Contracted position for the short flexor muscle endurance exercise. The subject lies supine with the knees bent to 90 degrees and the hands on the abdomen. *Note*. Adapted from "Reliability of a Measurement of Neck Flexor Muscle Endurance," by K.D. Harris, D.M. Heer, T.C. Roy, D.M. Santos, J.M. Whitman, and R.S. Wainner, 2005, Physical Therapy, 85(12), p. 1349.

Blizzard, Grimmer, and Dwyer (2000) included this endurance test in their reliability assessment regarding field measurement of cervical spine anthropometric and muscle performance factors. According to Harris et al. (2005) the reliability assessments by both Grimmer (1994) and Blizzard et al. (2000) were incomplete as both studies only tested intra-rater reliability. Furthermore, Grimmer (1994) only tested individuals without neck pain. Therefore, Harris et al. (2005) conducted a study to test neck flexor muscle endurance of both individuals with and without neck pain. The study by Harris et al. (2005) also investigated the inter-rater and intra-rater reliability of flexor endurance measurements. Neck flexor muscle endurance was statistically greater for subjects without neck pain than those with neck pain. While the results of this study reported acceptable test reliability for participants without neck pain, ICC values between 0.82 and 0.91, only moderate reliability was found for those with neck pain, ICC values from 0.67 to 0.78 (Harris et al., 2005). Although the study by Grimmer (1994) demonstrated reliability in healthy volunteers, the application of endurance measurements for neck injuries and rehabilitation had not been tested (Kumbhare et al., 2005). Therefore, Kumbhare et al. (2005) investigated measurement properties of the cervical flexor endurance test in whiplash patients. It was decided, however, that the method used by Grimmer (1994) was not appropriate for whiplash patients. Depending on which muscles were injured in a whiplash incident the full flexion position could not always be achieved, and may increase pain. The authors, therefore, adapted Grimmer's approach by including partial flexion. Although the results indicated high reliability from their clinical assessment, ICC = 0.96, the results cannot be compared to other studies due to differences in participant populations and testing procedures. The review by De Koning et al. (2008) rated the endurance test for short neck flexors positively for reliability, since the majority of studies using this test reported ICC values greater than 0.85. Based on their results, however, Harris et al. (2005) suggested that further investigations are needed in order for the neck flexor endurance test to be used as a reliable diagnostic and evaluative tool.

Manual muscle assessment differs from the neck flexor endurance test in that it involves resistive forces acting against the cervical muscles. This technique has most commonly been used for assessing cervical strength in the sagittal and transverse planes (Dvir & Prushansky, 2008). Testing is conducted with the participant in prone position for extension testing and supine position for flexion and rotation. From this position manual resistance is applied and strength is rated according to the MMT scale. According to this scale, Grade 1 represents an inability to maintain position against gravity, Grade 3 is equivalent to resisting gravity, and Grade 5 represents maintaining position against full manual resistance (Dvir & Prushansky, 2008). Only the study by Blizzard, Grimmer, and Dwyer (2000) was included in the review by De Koning et al. (2008) regarding manual muscle testing. Blizzard et al. (2000) investigated the intra-observer reliability for the manual testing of the long cervical flexors and extensors. Although high Kappa values were reported for both flexor and extensor muscles, 0.86 and 0.78 respectively, the manual muscle testing was rated doubtful in terms of reproducibility (De Koning et al., 2008). This low rating was received, as only healthy subjects were involved in the testing. Dvir and Prushansky (2008) further claimed that manual muscle testing is of low validity when strength is to be rated as Grade 4 or Grade 5 and is, therefore, not recommended for assessing cervical strength above Grade 3. For this reason manual muscle testing would not be appropriate for testing muscular strength development for training or rehabilitation purposes.

Dynamometry equipment exists as a handheld unit or as part of a fixed frame design. With a handheld dynamometer (HHD) a force-sensitive strain gauge, or a load cell, is integrated within an apparatus that is held by the examiner (Dvir & Prushansky, 2008). A strain gauge or load cell functions on the principle that when force is applied to a structure, the structure changes in form (Richards & Thewlis, 2008). Strain is the ratio of change between the original dimensions and the deformed dimensions (Richards & Thewlis, 2008). Strain gauges consist of material that when distorted produce a resistance. Therefore, force can be determined by measuring the resistance produced by the strain gauge. Similar to manual muscle testing, the examiner applies a resistive force against the muscle, using the handheld dynamometer. Equipped with a small screen the device records and displays the static force that the muscle exerts in response to the resistance, in units of kilogram-force, pounds, or Newtons. Tierney et al. (2005) used the Microfet Hand-Held Dynamometer (HHD) to assess head-neck segment isometric flexor and extensor muscle strength. Although the intra-tester reliability for the HHD was high, with an ICC of 0.96, the application of a HHD is somewhat impaired as the examiner is required to provide the resistive force and the proximal stabilization simultaneously (Dvir & Prushansky, 2008). In addition to the Microfet Dynamometer, De Koning et al. (2008) assessed the use of the Penny and Giles Hand-Held Myometer. Similar to the results of Tierney et al. (2005), the studies reviewed by De Koning et al. (2008) reported high ICC values in terms of inter-tester and intra-tester reliability. However, since the designs of the studies using HHD methods were incomplete the reliability of such studies was rated as doubtful (De Koning et al., 2008).

In fixed frame dynamometry (FFD) the load cell apparatus is no longer supported by the examiner, but is rather connected to a fixed base (Dvir & Prushansky, 2008). Pelvic and torso belts are included in the apparatus to ensure proximal stabilization as subjects are commonly tested in the seated position. Adjustments to the testing apparatus can also be made in order to fit individuals of varying heights. In comparison to the other isometric testing techniques, fixed frame dynamometry is the most preferred method for cervical strength testing. The diversity in testing procedures and resulting strength scores, however, is much greater among studies that use fixed frame dynamometry. For example, studies completed by Jordan, Mehlsen, Bulow, Ostergaard, and Danneskiold-Samsoe (1999), Suryanarayana and Kumar (2004), and Vasavada, Li, and Delp (2001) all aimed to quantify isometric cervical strength in flexion and extension. Although each study used fixed frame dynamometry for strength testing, different trends in strength scores were reported by each study. Suryanarayana and Kumar (2004) reported that cervical strength for both men and women was greatest in the neutral extension position. The average force produced in this position was 45.1 N for males and 39.5 N for females. Furthermore, participants exhibited a decrease in cervical strength with increased range of motion, as strength scores were measured at neutral, 25%, 50%, and 75% of flexion and extension. In the normative study by Jordan et al. (1999), maximal isometric strength was measured at 60^0, 45^0, 30^0, 15^0, and 0^0 of flexion and -15^0, 0^0, 15^0, 30^0, 45^0, and 60^0 of extension. Cervical strength for both men and women in this study was greatest at 45^0, of extension. At this position the average strength of male participants was approximately 60 N, while female participants recorded an average strength of about 50 N. Finally, Vasavada et al. (2001) reported the average maximum moments resolved at C7-T1 for men and women. Extension scores were 52 Nm for men and 21 Nm for women, while flexion values were 30 Nm for men and 15 Nm for women. Results from these studies demonstrate that men have stronger cervical muscles than women, as their strength scores are higher in each direction of neck movement. Additionally, neck extensors tend to be stronger than neck flexors in both men and women. Beyond these few generalizations, however, it is difficult to compare study results as each research group differed in test protocol. Isometric cervical strength studies differed in the type of equipment used, in the joint angles at which measurements were taken, the number of trials that were repeated and in the length of rest intervals between trials. As a result, each study recorded varying strength results.

Rezasoltani, Ahmadi, Jafarigol, and Vihko (2003), Leggert et al. (1991) and Ylinen, Rezasoltani, Julin, Virtapohja, and Malkia (1999) all tested the reliability of repeated isometric strength measurements using fixed frame dynamometers. Although the reported ICC values were all equal to or greater than 0.94, the testing device used by each group differed again in structure and design. Rezasoltani et al. (2003) measured the force generated by the cervical extensor and flexor muscles using a device that consisted of two parallel bars fixed to the wall. A load cell was mounted in a box and its level was horizontally and vertically adjustable. The thorax and pelvis stabilizers were also adjustable according to body size and were fixed by two straps at the level of spine of scapula and iliac spine, respectively. Once adjusted to the device, subjects sat with head and neck in neutral position. The load cell was positioned against the occipital bone to measure cervical extension force and against the frontal area for cervical flexion force measurements. Leggert et al. (1991), used a MedX cervical extension machine to measure maximum voluntary isometric cervical extension strength at 126^0, 108^0, 90^0, 72^0, 54^0, 36^0, 18^0, and 0^0 cervical flexion. Similar to the device used by Rezasoltani et al. (2003), the MedX machine consisted of an adjustable seat and restraining belts to stabilize the torso. This device, however, included a shoulder harness, seat belt, and torso restraint. The torso restraint consisted of two pads mounted on an adjustable crank that were placed against the anterior of the chest, below the clavicles. No head strap was included in the MedX measuring device. Finally, Ylinen et al. (1999) evaluated the reliability of an isometric measurement device designed to test neck flexion, extension and rotation. The headpiece of this equipment was more extensive consisting of two adjustable pads positioned on the skull of the participant and cheek supports to further prevent head movement. The load cell was connected to the headpiece to measure resistive forces. The chest and waist were tightly fixed to bars that projected out from the stand with straps. Like the two previous studies, these straps were at the level of the iliac spine and above the lower border of the scapula. Due to the differences in testing devices the strength scores and ICC values differed between studies, once more making it difficult to compare results. The review by Dvir and Prushansky (2008) included a table listing similar isometric studies. The table identified the testing device that was used in each study as well as the strength scores that were reported. In comparing the flexion strength of women alone, the reported scores ranged from 20 N to 100 N (Dvir & Prushansky, 2008). Although isometric studies have reported high tester reliability, application of the results is limited as no standardized equipment or procedure has been established, and reported data is inconsistent. Potach and Borden (2000) also explained that isometric strengthening is joint-angle specific, which means that strength gains only occur at the angles used. Therefore, isometric testing is inappropriate for assessing changes in strength during dynamic training (Kraemer, Ratamess, Fry, & French, 2006).

Isokinetic neck testing techniques.

Similar to isometric techniques, isokinetic testing methods measure the muscular force that is applied during maximal contraction against a resistance. Isokinetic testing differs, however, as the body segment under investigation can move through a selected or full range of movement during the contraction of the assessed muscle (Potach & Borden, 2000). During the flexion and extension components of the movement the muscle shortens and lengthens, respectively. The movement, however, is initiated and controlled by one of several specialized testing devices. According to Dvir and Prushansky (2008) isokinetic dynamometry is recognized as the standard method for dynamic muscle testing. Suryanarayana and Kumar (2005), agree that isokinetic dynamometers (ISD) are reliable devices for measuring muscle performance. The disadvantages to isokinetic strength testing, however, include high equipment costs, large space requirements, time consuming testing sessions, and the need for trained personnel. Additionally, when using any of the accepted isokinetic dynamometers researchers are required to provide their own modifications to the testing apparatus as the manufactures do not provide a standard cervical attachment (Dvir & Prushansky, 2008). The guidelines provided by Du Toit, Buys, Venter, and Olivier (2003), however, described the requirements necessary for any ISD to accurately evaluate cervical muscle strength. The subject's torso must be fully stabilized; measurements should be made through a full range of joint motion; correction for the influence of gravitational force should be made during assessment; and a standardized testing protocol should be used. Such recommendations ensure that equipment and protocol are more consistent between studies, leading to more reliable results.

The device used by Du Toit, Buys, Venter, and Olivier (2003) satisfied all of the above requirements, consisting of a standard isokinetic dynamometer head mounted to the back of a stabilizing chair, with a specially designed halo attached to it. The dynamometer was connected to a computer that recorded and displayed participants' cervical flexion, extension, and lateral flexion strength while moving at an angular velocity of 30^0/s. The results demonstrated a high reliability in repeated measures of cervical strength (ICC = 0.89). In addition to the previous guidelines, these researchers advised that a familiarization session is essential for accurate strength assessment. Olivier and Du Toit (2007) used the same testing device and protocols in a later study that delineated the isokinetic neck strength profile of senior elite rugby players. Isokinetic neck strength variables were additionally compared among various positional categories. The protocol used by Deslandes, Mariot, and Colin (2008) was also similar to that used by Du Toit et al. (2003), while the dynamometer met the recommended guidelines. The measuring device consisted of two sub-units that hooked onto a single-arm Biodex dynamometer. The headpiece involved a frame that connected the motor of the device with the subject's head using a full face motorcycle helmet. An adjustable arm attached the head frame to the dynamometer axis while the subject was stabilized in a seated position, inside an adjustable body frame. Using this apparatus, participants were tested in both the frontal and sagittal plane, moving at a speed of 30^0/s. Thus, it appears that there is more consistency among studies that use isokinetic testing techniques in comparison to isometric research. A comparison of data among isokinetic studies, however, is still difficult as study objectives and participants vary. Furthermore, since no sport or activity is performed at a constant speed isokinetic exercise and functional testing is limited in its real-world or sport application (Potach & Borden, 2000).

Isotonic neck testing techniques.

Isotonic movement uses concentric and eccentric muscle action to move a corresponding body segment through a full range of motion (Potach & Borden, 2000). As there is constant external resistance acting against the muscle, the muscle either shortens or lengthens depending on whether the contractile forces are greater or less than the resistive force. The amount of force required to move the resistance varies, depending primarily on joint angle and the length of each agonist muscle (Potach & Borden, 2000). The speed at which the movement occurs is also controlled by the individual being tested rather than a testing device therefore, making it more comparable to the physical action involved in sport. In comparison to isometric and isokinetic testing, literature regarding isotonic cervical muscle testing is extremely limited. This void may be due to the heightened vulnerability of the cervical neck and the increased risk of injury associated with isotonic exercise and strength testing. When proper precautions are used, however, isotonic strength testing provides valuable information concerning cervical muscle strength and function, as demonstrated in the following studies.

Despite the array of studies that assessed the cervical musculature through isometric and isokinetic techniques, limited research has investigated the function of individual neck muscles during various movements of the head (Conley, Stone, Nimmons, & Dudley, 1997a). To gain a greater understanding of neck muscle functioning Conley, Stone, Nimmons, and Dudley (1997a) used magnetic resonance imaging (MRI) to examine neck muscle activation patterns that were evoked by various head movements. Neck muscle activation patterns were analyzed during flexion, extension, lateral flexion, and rotation. Of these various movements a more complex muscle action was observed during neck extension. An additional testing approach was, therefore, conducted to further investigate muscle action during cervical extension (Conley, Stone, Nimmons, & Dudley, 1997b). In their follow-up study, Conley et al. (1997b) used MRI to analyze muscle strength and hypertrophy following 12 weeks of isotonic extension resistance training. The study enabled researchers to further analyze which specific muscles were used for neck extension by comparing muscle cross-sectional area before and after the training period. Conley et al. (1997b) concluded that for resistance training to provide sufficient stimulus for increases in cervical muscle size and strength, specific isotonic neck exercises must be performed. Although conventional resistance exercise programs incorporate isometric neck muscle contractions, the stimulus is not enough to elicit increases in neck muscle size or strength.

The two studies by Conley et al. (1997a & 1997b) provide a more in depth understanding of cervical extensor functioning through isotonic training and MRI analysis. Less research, however, has focused on the functioning of cervical neck flexors and how these muscles respond to isotonic training. Although both muscle groups have responded positively to isometric training, Deslandes, Mariot, and Colin (2008) and Suryanarayana and Kumar (2005), found that the cervical flexors were a much weaker muscle group than the extensors in terms of isometric strength. Therefore, it is likely that less resistance is needed during isotonic training of the cervical flexor muscles, as compared to neck extensors, in order for increased strength and muscle hypertrophy to occur. Further muscle analysis is important to understanding how the cervical flexor and extensor muscles differ in response to isotonic training. Furthermore, a significant strength imbalance between the cervical flexor and extensor muscles could be a predisposing factor for neck injury in sport as the stability of the cervical spine is reduced. Examining cervical flexion and extension strength of athletes would be beneficial to identifying muscle weakness and prescribing appropriate isotonic neck strengthening programs. As magnetic resonance imaging is not a readily available testing technique a more accessible method for isotonic neck muscle assessment is needed.

An additional study by Burnett, Coleman, and Netto (2008) used surface EMG to compare neck muscle activation during two different isotonic training modalities, the Cybex machine and Thera-Band resistance tubing. The Cybex is an isotonic machine that can readily alter exercise intensity by adjusting a pin-loaded stack. The Thera-Band latex tubing is available as color-coded bands of varying thickness, theoretically providing different resistances and altering exercise intensity (Burnett, Coleman, & Netto, 2008). Although these modalities are used for developing neck muscle strength and endurance, there is little empirical evidence available on how changes in exercise intensity actually affect neck muscle activation. Therefore, EMG technology was used to examine muscle activation in response to various exercise intensities and neck movements, including flexion, extension and lateral bending. The EMG activation related to all Thera-Band exercises was significantly lower than those produced during Cybex exercises. Additionally, significant differences in EMG activation were more evident when comparing intensities of the Cybex (Burnett et al., 2008). Increasing the intensity of Thera-Band exercises had little effect on muscle activation. In terms of practical implications, these researchers suggested that the Thera-Band exercises be used for cervical spine rehabilitation programs. Cybex exercises were recommended for more intense training and neck injury prevention. Burnett et al. (2008) also reported that peak and average levels of muscle activation elicited during the concentric and eccentric portions of the cervical flexion and extension contractions were highly reliable for both the Thera-band and Cybex modalities, ICC values ranged from 0.66 to 0.98. Although MRI and EMG analysis may provide valuable information concerning cervical muscle functioning, neither test modality specifically measures muscular strength.

Repetition maximum testing.

As demonstrated in the previous sections, dynamic muscle assessment can be done in a laboratory setting or human performance facility using various technical equipment and devices. Lab testing, however, is not always practical for meeting the volume of tests that coaches, trainers, and athletes request (Brzycki, 1993). For this reason the 1 repetition maximum (1-RM) test has become the most popular way to assess dynamic strength. Kraemer, Ratamess, Fry, and French (2006) defined a 1-RM test as the maximal amount of weight that can be lifted once for a specific exercise. A 1-RM exercise can be completed using free weights or a specific weight machine, both methods relying on isotonic movement. The muscle group being tested shortens as it contracts in order to move the corresponding body segment through a range of motion, thereby overcoming the external resistance of the free weight or weight machine. An individual's 1-RM for a specific exercise is identified when the external resistance is greater than the contractile force of the tested muscle group. Kraemer et al. (2006) explained that 1-RM testing is, therefore, advantageous for strength assessment as it does not require extensive equipment and reflects the kind of muscle activation necessary in many sports. Furthermore, 1-RM testing is exercise specific. This means that strength measurements can accurately be attributed to a particular muscle group, providing a more sport specific assessment.

Kraemer, Ratamess, Fry, and French (2006) provided data displaying the test-retest reliability for various 1-RM testing protocols (Table 1). As shown, high interclass coefficients were reported throughout the various 1-RM strength tests, ranging from $R = 0.69$ to 0.99. Data provided by Kraemer et al. (2006) also demonstrates the range of muscle groups that can be evaluated using a 1-RM test protocol. Although larger muscle groups are more commonly assessed for 1-RM strength, through exercises such squat, bench press and leg press, smaller muscle groups have also been examined using 1-RM testing. Despite the range of muscles that have been evaluated using 1-RM strength tests the literature does not include any data related to 1-RM testing of the cervical muscles. This further demonstrates the lack of research associated with isotonic cervical strength testing. However, 1-RM testing may be inappropriate for assessing neck strength due to the increased vulnerability of the cervical spine and risk of injury involved. For this reason it would be more appropriate to use a submaximal test completed to fatigue to predict an athlete's 1-RM neck strength.

Table 1

Test-Retest Reliability for Various 1-RM Testing Protocols

Exercise	Coefficient	Reference
Squat	0.94	Sewell & Lander (1991)
	0.99	Giorgi et al. (1998)
	0.95	Hickson, Hidaka, Foster, Falduto, & Chatterton (1994)
	0.92	Sanborn et al. (2000)
	0.99	McBride, Triplett-McBride, Davie, & Newton (2002)
Bench Press	0.98	Sewell & Lander (1991)
	0.99	Giorgi et al. (1998)
	0.98	Kraemer et al. (2000)
	0.99	Rhea, Ball, Phillips, & Burkett (2002)
	0.99	Hickson et al. (1994)
Leg Press	0.89	Hoeger et al. (1990)
	0.99	Kraemer et al. (2000)
	0.99	Rhea et al. (2002)
	0.69-0.91	Patterson, Sherman, Hitzelberger, & Nichols (1996)
Lat Pulldown	0.79-0.98	Hoeger et al. (1990)
	0.92-0.98	Patterson et al. (1996)
Shoulder Press	0.98	Kraemer et al. (2000)
	0.97-0.98	Patterson et al. (1996)
Leg Extension	0.92-0.98	Hoeger et al. (1990)
Leg Curl	0.93-0.97	Hoeger et al. (1990)
Sit-up	0.98	Hoeger et al. (1990)
Arm Curl	0.86-0.97	Hoeger et al. (1990)
	0.98	Sale et al. (1998)

Note. Adapted from *Physiological Assessment of Human Fitness,* p. 130, by Kraemer, Ratamess, Fry, & French, 2006, Champaign, IL: Human Kinetics

According to Dohoney, Chromiak, Lemire, Abadie, and Kovacs (2002), prediction of 1-RM strength can be used to assess an individual's maximal lifting capacity without subjecting the participant to the increased risk associated with some 1-RM lifts. Furthermore, because of the physiological nature of most contact sports a multiple RM test may be more consistent with the training techniques utilized by these athletes. Such athletes would rarely partake in 1-RM training as it would be of little benefit to their sport performance. Most athletes would benefit more from strength developing workouts, which involve multiple repetitions at a percentage of the athletes' 1 repetition maximum. Therefore, a 4 to 6-RM cervical strength test would be more suitable as it does not require a maximal lift, yet involves a repetition range that is consistent with strength development programs. According to Baechle, Earle, and Wathen (2000), training programs designed for developing strength should assign four to six repetitions for each exercise. Training programs with repetitions less than this are intended for developing maximal power, while six to 12 repetitions would be assigned for muscle hypertrophy. Repetitions above 12 would be suitable for programs aimed at muscle endurance. Therefore, a 4 to 6-RM test completed to fatigue would be most consistent with the exercise prescription of these athletes.

Once multiple RM data is collected 1-RM capabilities can be predicted using an appropriate equation. LaSuer, McComick, Mayhew, Wasserstein, and Arnold (1997) evaluated the accuracy of seven 1-RM predicting formulas (Table 2). Each formula was used to estimate the 1-RM for bench press, squat, and deadlift from a common data set based on repetitions to fatigue. The accuracy of each prediction equation was then evaluated by comparing the predicted 1-RM values to the achieved 1-RM of each exercise (Table 3). In regards to predicting deadlift performance, all seven formulas significantly underestimated 1-RM performance. Similar results were found when evaluating the formulas for predicting bench press and squat performance. Only the Wathen (1994) formula predicted 1-RM values that did not differ significantly from the achieved 1-RM values in both squat and bench press performance. Although no maximal or submaximal testing has been completed for evaluating neck strength, it appears that the Wathen (1994) formula is most accurate for predicting a 1-RM from a repetitions to fatigue test.

Table 2

1-RM Prediction Equations

Author	Equation
Brzycki (1993)	1RM = 100 x W / (102.78 - 2.78 x R)
Epley (1985)	1RM = (1 + 0.333 x R) x W
Lander (1985)	1RM = 100 x W / (101.3 - 2.67123 x R)
Lombardi (1989)	1RM = W x $(R)^{-1}$
Mayhew et al. (1992)	1RM = 100 x W / (52.2 + (41.9 x $e^{-0.055 \times R}$))
O'Conner et al. (1989)	1RM = W (1 + .025 x R)
Wathen (1994)	**1RM = (100 x W) / (48.8 + (53.8 x $e^{-0.075 \times R}$))**

Note. Adapted from "The Accuracy of Prediction Equations for Estimating 1-RM Performance in the Bench Press, Squat, and Deadlift" by D.A. LaSuer, J.H. McComick, J.L. Mayhew, R.L. Wasserstein, and M.D. Arnold, 1997, *Journal of Strength and Conditioning Research, 11*(4), p.211. *W* = weight used to complete the last set of repetitions of the submaximal test; *R* = number of repetitions completed for the last set of the submaximal test; *e* = a mathematical constant equal to 2.71828.

Table 3

Comparison of Predicted 1-RM Values with Achieved 1-RM Scores

Authors	Predicted 1-RM (lbs) *M*	*±SD*	Diff. between achieved & predicted *M*	*±SD*	Diff. as % of 1-RM achieved	Correlation	*t*
Bench Press							
Brzycki	131.9	60.6	5.4	7.6	4%	0.993	5.87**
Lander	133.0	61.1	4.3	7.5	3%	0.993	4.68**
Epley	135.1	62.1	2.2	7.5	1%	0.993	2.43**
Lombardi	133.0	61.2	4.3	8.6	3%	0.990	4.14**
Mayhew	136.2	62.4	1.1	8.0	0.8%	0.992	1.16
O'Conner	129.1	59.2	8.2	8.1	6%	0.992	8.22**
Wathan	136.1	62.7	1.2	7.7	0.8%	0.992	1.22
1-RM achieved mean = 137.3, standard deviation = 62.1							
Squat							
Brzycki	197.3	75.1	10.7	18.8	0.05%	0.969	4.4**
Lander	198.9	75.7	9.1	18.8	0.04%	0.969	3.7**
Epley	201.3	76.5	6.7	19.0	0.03%	0.968	2.7**
Lombardi	196.8	74.5	11.2	19.7	0.05%	0.965	4.4**
Mayhew	196.8	74.6	11.2	19.7	0.05%	0.965	2.5**
O'Conner	191.5	72.6	16.5	18.9	0.08%	0.968	6.7**
Wathan	203.4	77.4	4.6	17.2	0.02%	0.969	1.8
1-RM achieved mean = 208.0, standard deviation = 74.6							
Deadlift							
Brzycki	207.4	88.3	29.1	26.8	12%	0.956	8.3**
Lander	209.2	89.1	27.3	26.8	11%	0.956	7.7**
Epley	212.5	90.3	24.0	27.1	10%	0.956	6.7**
Lombardi	209.1	89.2	27.4	28.4	11%	0.951	7.3**
Mayhew	213.9	91.3	22.6	28.0	10%	0.953	6.1**
O'Conner	202.8	86.5	33.7	27.5	14%	0.954	9.3**
Wathan	214.3	91.0	22.2	27.1	9%	0.965	6.2**
1-RM achieved mean = 236.5, standard deviation = 91.7							

$^{**}p < 0.01$

Note. From "The Accuracy of Prediction Equations for Estimating 1-RM Performance in the Bench Press, Squat, and Deadlift" by D.A. LaSuer, J.H. McComick, J.L. Mayhew, R.L. Wasserstein, and M.D. Arnold, 1997, *Journal of Strength and Conditioning Research, 11*(4), p.211.

A predictive 1-RM cervical strength test would be a valuable contribution to the literature regarding cervical muscle strength and functioning and for neck muscle assessments. In addition to assessing cervical strength and monitoring isotonic cervical training, a predictive 1-RM strength test would be beneficial for evaluating cervical muscle endurance, and neuromuscular fatigue of athletes. As Armstrong, McNair, and Taylor (2008) reported local muscle fatigue could be an impeding factor against optimal proprioceptive performance of the cervical muscles. Muscle fatigue may, therefore, reduce the speed and strength of cervical muscle contractions, which is essential to preventing serious neck injury during head impact. A predictive 1-RM test for the neck would also be useful for examining the effects of isotonic resistance training used in rehabilitation programs. According to Ylinen and Ruuska (1994), a three week rehabilitation program resulted in improved neck muscle strength and reduced symptoms in patients suffering from persistent neck pain. Although the program utilized both isometric and isotonic exercises the researchers evaluated neck muscle strength using only an isometric testing technique. Therefore, the results and conclusions may be questionable as the testing technique was inconsistent with the training modality. Normative 1-RM data could also be developed from predictive tests, which may assist trainers and coaches of various sports establish return to play criteria following neck injury. Such data could additionally be used in sports such as football and rugby for determining the required neck strength of certain positions that are more prone to neck injury.

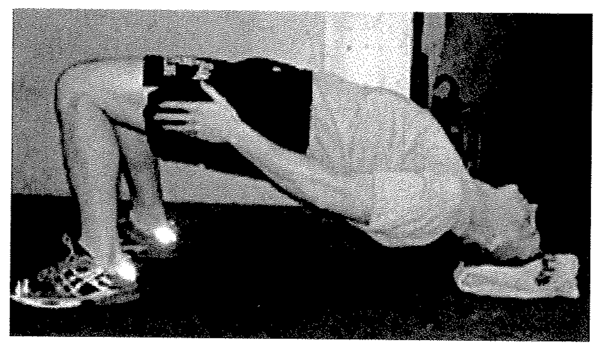
Research Problem

Strengthening of the neck musculature can reduce the risk and severity of neck injuries associated with contact sports and assist athletes in improving sports performance (Cross & Serenelli, 2003; Cooper, McGee, Anderson, 2003; Tator, Carson, & Cushman 2000; Tator &

Edmonds, 1984; Wroble & Albright, 1986). According to Cross and Serenelli (2003) a cervical strength training program for any athlete involved in contact sport should begin with isometric exercise and progress to include isotonic workouts. Such training enhances the athlete's ability to effectively stabilize the neck while developing proprioception and contractile force of the neck muscles. This development is essential to minimizing neck injury as it improves the speed and strength of muscular contractions, enabling the athlete to achieve appropriate neck tension at impact. Additionally, cervical spine stability is important for maintaining proper posture for optimal performance. Finally, cervical muscle hypertrophy from isotonic training may aid in the dissipation of energy from impact forces to the head.

In order to monitor the effectiveness of a cervical training program regular assessment of cervical muscle strength should also be completed (Kraemer, Ratamess, Fry, & French, 2006). The protocol used for assessing muscular performance, however, should be specific to the training modality (Kraemer, Ratamess, Fry, & French, 2006). Although isometric testing is useful for evaluating neck strength during the initial stages of a sports training program, an isotonic testing method should be used for assessing neck strength during later stages of conditioning. Since laboratory equipment, such as electromyography (EMG) and magnetic resonance imaging (MRI), is not easily accessible or affordable for athletes or sport teams a more appropriate method for isotonic neck muscle assessment is required. A predictive 1-RM neck test may be a simple and effective method for assessing athletes' isotonic neck strength and monitoring isotonic cervical training. No research, however, has measured the absolute 1-RM or predicted 1-RM strength for any neck movement. Although researchers have developed numerous isometric tests for assessing neck strength, no study has examined the relation between maximal isometric and predicted 1-RM cervical strength values. Correlations between isometric and isotonic strength values would confirm whether specific measures of muscle function are required, or if various muscle capabilities can be generalized from a single cervical strength test. Furthermore, no study has compared the cervical anthropometrics or neck strength profiles of athletes involved in various contact sports. Such research would provide insight into the training effects of the cervical muscles and assist coaches and trainers in prescribing appropriate cervical training programs for athletes.

Ice hockey and wrestling are two contact sports in which specific trends in neck injuries have been observed (Boden & Prior, 2005; Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, Ylinen, 2005; Tator, Carson, & Edmonds, 1998; Wroble & Albright, 1986). The risk and severity of the neck injuries common to each sport, however, differ substantially. Furthermore, there is a considerable difference in the degree of cervical strength training commonly followed by each type of athlete. Research shows that there is an increased risk of catastrophic spine injury associated with ice hockey. Concussion and whiplash injuries can result from situations where a player collides with the boards or receives an unexpected check from another player. Most serious neck injuries involve a headfirst impact into the boards, which causes axial loading to the cervical spine (Tator, Carson, & Cushman, 2000). The resultant injury is commonly a fracture-dislocation or burst injury at the fifth and/or sixth cervical vertebra. Depending on the force and direction of the impact the severity of this injury can range from a mild concussion to complete paralysis. Although cervical strength training has been cited as an injury prevention strategy, few hockey players include specific neck strengthening exercises in their training program and are rarely encouraged to do so by coaches and trainers (Tator, 1984). In contrast to ice hockey, catastrophic neck injuries in wrestling are rare (Wroble & Albright, 1986; Halloran, 2008). Instead overuse injuries to the cervical muscles and ligaments are much more prominent, typically resulting from repetitive force overload or excessive training (Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, & Ylinen, 2005). The most common neck injuries associated with wrestling are cervical muscle strains and sprains (Wroble & Albright, 1986; Rezasoltani et al., 2005). The low incidence of catastrophic neck injuries in wrestling may be attributed to the specific neck training exercises that are standard to most wrestling programs. Neck strengthening exercises, such as the neck bridging shown in Figure 2.9, routinely constitute a significant part of a wrestler's training program (Grindstaff & Potach, 2006).



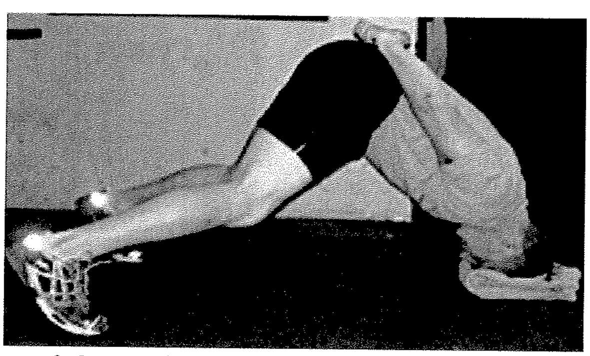


Figure 2.9. Neck strengthening exercises commonly included in a wrestler's training program. *Note*. Adapted from "Prevention of Common Wrestling Injuries" by T.L. Grindstaff, and D.H. Potach, 2006, National Strength and Conditioning Association, 28, p. 20.

Research objectives.

There were two main objectives to this study. The first was to examine the relation between maximal isometric neck force and predicted 1-RM cervical strength values, for neck flexion and extension. The second was to compare maximal isometric and predicted 1-RM neck strength values among three groups of participants, including wrestlers, hockey players, and kinesiology students.

Research questions.

1. Is there a relationship between maximal isometric and predicted 1-RM cervical strength values, for neck flexion and extension?
2. How does maximal isometric and isotonic (predicted 1-RM) neck strength compare among athletes in various contact sports, such as ice hockey and wrestling?

Hypotheses.

There were two hypotheses generated for this study.

1. There is a positive relationship between maximal isometric neck force and predicted 1-RM neck strength values for both cervical flexion and extension. That is, participants with higher isometric strength scores will perform better on the isotonic strength tests, resulting in higher predicted 1-RM values.
2. Trained athletes demonstrate greater isometric and isotonic neck strength than a healthy control group. Wrestlers show greater isotonic neck strength than hockey players due to differences in their strength training programs.

CHAPTER THREE-METHODOLOGY

Participants

This study tested the isometric and isotonic neck strength of three groups of participants. Two groups consisted of high-caliber athletes, who regularly followed a sports specific training program. The first group of athletes included hockey players from the Lakehead University varsity hockey team and from the Thunder Bay North Stars. The North Stars are a part of the Superior International Junior Hockey League. The second group was comprised of Lakehead University varsity wrestlers. The third group of participants served as a control group. It consisted of individuals currently involved in recreational sport and/or physical activity. Third and fourth year kinesiology students were recruited for this group of participants as these students typically engage in recreational activity and understand the importance of physical fitness.

Each group consisted of eight male participants, between the ages of 18 and 24, all of whom were tested for isometric and isotonic neck strength. At the time of testing, the wrestlers and hockey players had participated in their sport for a minimum of three years at a competitive level, during which they were actively involved in a sports specific training program. Individuals in the control group had participated in moderate, nonspecific activities for general health and fitness or recreational sport for a period of at least three years.

Individuals who volunteered to participate in this study were pre-screened for abnormal neck functioning and increased risk of neck injury. To be cleared for participation individuals were required to demonstrate normal cervical active range of motion (AROM), without neck pain, when assessed by the student researcher and supervisor. Normal values of cervical active range of motion required for participation in this study were adapted from Youdas et al. (1992)

and are presented in the Pre-screening Assessment Form (Appendix A). Questions regarding past neck injuries and current neck pain were also included in the Pre-screening Assessment Form and were adapted from the admission criteria used by Youdas et al. (1992). An individual who answered "yes" to any of the questions on the Pre-screening Assessment Form, or who did not demonstrate normal cervical active range of motion, was excluded from further participation in this study. All prerequisites for participation were outlined in the cover letter and the consent form that individuals were required to sign prior to participation (Appendix B & C). As all participants were a minimum of 18 years old, parental consent was not required for involvement in this study.

In order to keep participant identity confidential and anonymous each athlete and kinesiology student was assigned a reference number (Hockey Player 1-8, Wrestler 1-8, and Control 1-8). The reference numbers were used to report all test results and no names or identifiable information were linked to test data. The Lakehead University Research Ethics Board approved all methods used for cervical strength testing and data collection.

Recruitment Procedures

The student researcher contacted the coaches of the Lakehead University wrestling and hockey teams and the coach of the Thunder Bay North Stars. The purpose of the study was presented to each coach and permission was sought to speak to his or her athletes as potential participants. An information session was held following a practice or training session with each team and was open to all athletes, coaches, and trainers. The information sessions were used to explain the purpose of this study to the athletes, answer any questions or concerns relating to participation, and to schedule three test days with each individual that volunteered to participate.

An email was sent out to third and fourth year kinesiology students from the School of Kinesiology at Lakehead University explaining the purpose and details of this study. The name and contact information of the student researcher and supervisor was provided in the email as well. Additionally, the student researcher presented the study to several third and fourth year kinesiology classes. Any student agreeing to participate either contacted the student researcher to receive an information letter and consent form or volunteered at the end of the class presentations. Three test days were then scheduled with each student volunteer.

Instrumentation

Anthropometric assessments.

Participant height, mass, head-neck segment length, and neck girth were measured and recorded in the Data Collection Charts (Appendix D). Participants' heights were measured in centimeters using a metric tape measure. Mass was assessed in kilograms using the digital scale located in the Lakehead University Exercise Physiology Lab (SB 1025). Head-neck segment length and girth was assessed using measurement guidelines provided by Olivier and Du Toit (2008). A metric tape measure was used to take these measurements while the participant sat on a chair with their feet planted on the floor, maintaining a straight back and looking at an object positioned at eye height on the wall directly in front. Head-neck segment length was measured from the spinous process of the vertebral prominence (C7) to the occipital notch at the base of the skull. Neck girth measurements were taken directly superior to the thyroid cartilage. All anthropometric measurements were taken by the student researcher.

Neck strength measurements.

Participants completed isometric and isotonic cervical strength tests for neck flexion and extension using the Nautilus neck strengthening machine located in the Lakehead University Exercise Physiology Laboratory (SB 1025). The Nautilus machine was chosen to evaluate neck strength because it is a standard piece of equipment used for strengthening the neck musculature (Figure 3.1). The Nautilus machine was positioned 1 foot from the concrete wall of the lab and bolted to the floor. A strain gauge load cell was secured to the wall behind the Nautilus machine at the same height as the head pads on the weight machine. The load cell was attached to the moveable arm of the Nautilus equipment with a lightweight chain and was designed to measure the force produced during the isometric strength tests (Figure 3.2). The Nautilus machine was also used to complete a 6-RM submaximal test to fatigue for neck flexion and extension in order to measure isotonic neck strength. The 6-RM tests were completed by incrementally adding weight plates to the moveable arm of the Nautilus machine according to guidelines provided by Kraemer, Ratamess, Fry, and French (2002). Data from the 6-RM tests was then entered into the Wathen (1994) equation to predict participants' 1-RM for cervical flexion and extension. A Biometrics electrogoniometer was also attached to the moveable arm of the Nautilus machine to monitor the range of neck movement during isotonic neck testing.

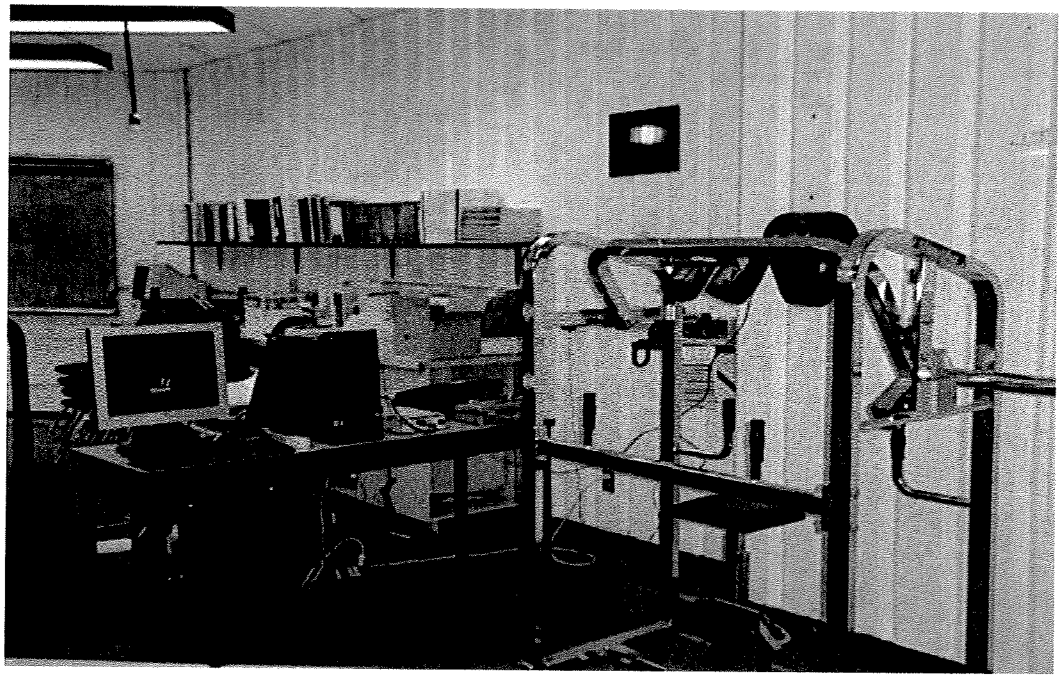


Figure 3.1. Nautilus neck strengthening machine and testing equipment in the Lakehead University Exercise Physiology Laboratory (SB 1025).

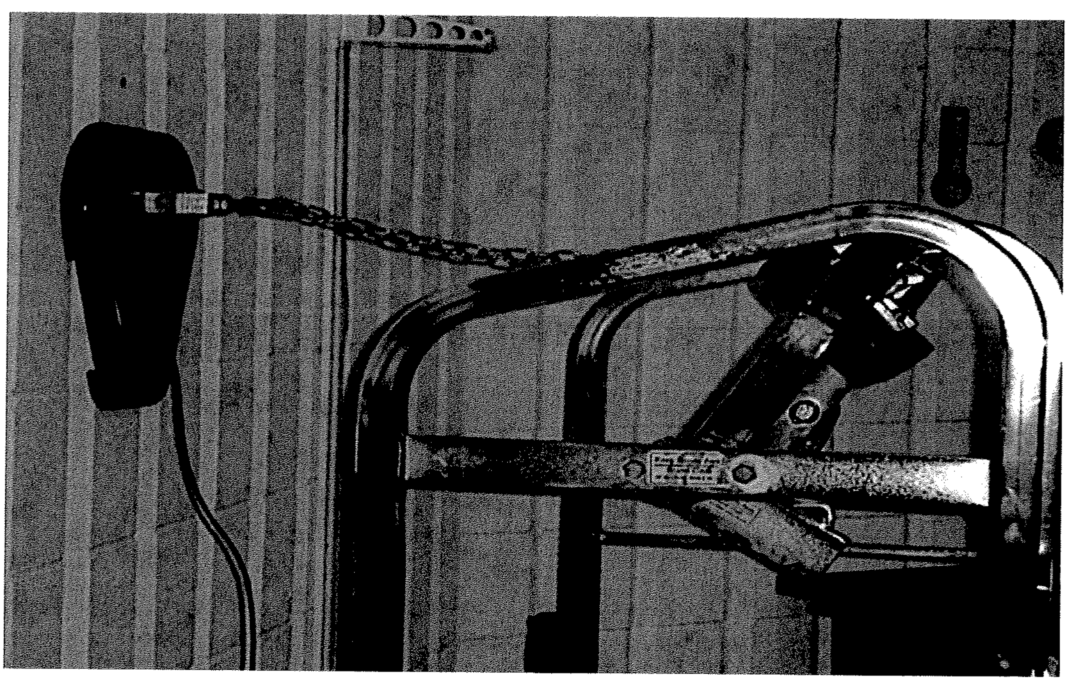


Figure 3.2. Nautilus machine attached to the strain gauge load cell to measure maximal isometric neck strength.

Validity and Reliability Assessment

The test equipment was assessed for both validity and reliability. First, a Chatillon digital force gauge (Figure 3.3) was used to evaluate the concurrent validity of the strain gauge load cell. Using the Chatillon gauge a resistance force was produced against the load cell (Figure 3.4). The peak force measured by the Chatillon gauge, in Newtons, was then compared to the force measured by the strain gauge, in volts. This comparison showed a linear relationship between the two measurements, with a Pearson R value of 0.99, which provided evidence that the strain gauge load cell is a valid measurement tool that accurately measures the resistance force that is applied to it.

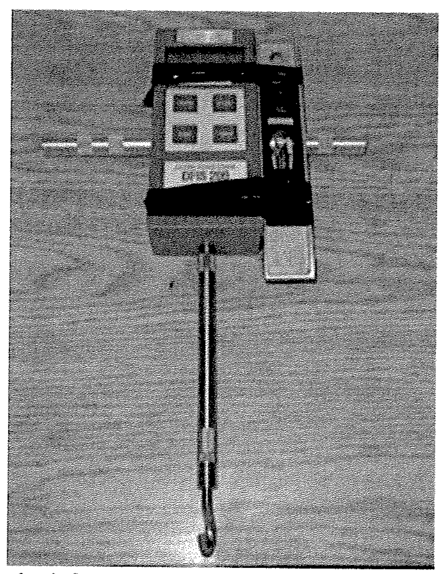


Figure 3.3. Chatillon digital force gauge used to evaluate the concurrent validity of the strain gauge load cell. A level was attached to the Chatillon gauge to ensure the direction of the resistance force was the same throughout the validity testing.

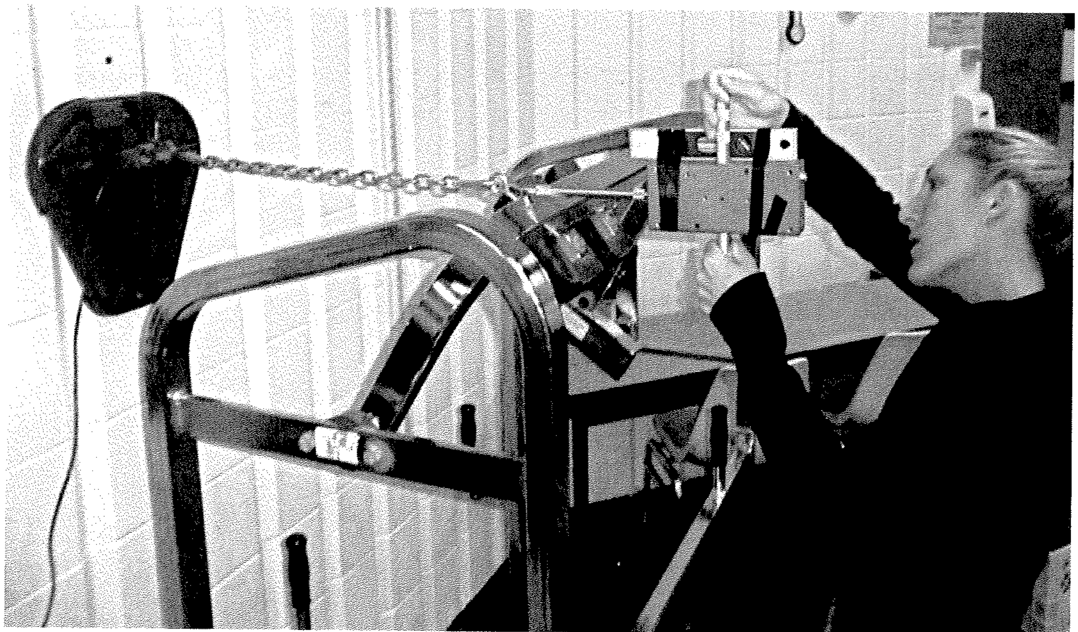


Figure 3.4. The strain gauge load cell and the Chatillon digital force gauge were simultaneously attached to a bolt that was added to the moveable arm of the Nautilus machine. By pulling on this bolt with the Chatillon gauge a resistance force was generated against the strain gauge load cell. The peak force measured by the Chatillon gauge was then compared to the force measured by the strain gauge in order to assess the validity of the equipment that was used for assessing isometric neck strength.

To assess the reliability of the test equipment, various weight plates were hung from the moveable arm of the Nautilus machine, which created a pulling force on the load cell. The force produced on the load cell by each combination of weight plates was converted from volts to Newtons. The force, in Newtons, was then compared to the weight of each plate combination. A total of twenty measurements were taken, using the same combinations of weight plates, to ensure that there was consistency across replications. The interclass correlation between force values was 0.97, indicating that the equipment set-up was highly reliable.

Testing Procedures

Prior to any testing participants were provided with information letters and consent forms. The information letter outlined the purpose and procedures of the study and indicated any potential for physical harm that was associated with participation. This letter also ensured participants that all measures would be taken to prevent any physical injuries from occurring. Prior to any testing, the student researcher ensured that every participant signed the consent form, and completed a PAR-Q (Appendix E).

The first scheduled session was used to complete the prescreening assessment, take anthropometric measurements and familiarize participants with the testing equipment and procedures. During the second test session participants completed either the isometric or the isotonic testing protocol. The remaining testing technique, isometric or isotonic, was then completed at the third and final test session. Each session was scheduled three to five days apart at approximately the same time of day. The order in which isometric and isotonic testing was completed was randomly assigned to each participant so as to eliminate the risk of any learning effect. Additionally, the order of cervical flexion and extension exercises were randomly assigned to participants at each session.

Anthropometric measurements & familiarization session.

The anthropometric measurements were taken as previously described and were entered into the Data Collection Charts (Appendix D). The familiarization session was then completed according to guidelines provided by Kraemer, Ratamess, Fry, and French (2002).

Warm-up & stretching routine.

Participants were first guided through an appropriate warm-up and dynamic neck stretching routine (Appendix F). The warm-up began with 5-minutes of light biking in order to raise the body's internal temperature. This allowed for a greater amount of muscle flexibility and reduced the risk of muscular injury (Holcomb, 2000). Dynamic stretches included flexion, extension, lateral flexion, rotation, and retraction movements performed through a full range of motion at a slow continuous pace without resistance. As recommended in the literature two sets of 10 repetitions were completed for each dynamic neck movement in the warm-up routine (Harman & Pandorf, 2000). This warm-up routine was based on the dynamic movements involved in the neck testing procedures, and was designed to increase blood flow to the cervical muscles and to ensure that the neck muscles were properly prepared to perform specific resistance exercises. A specific pre-test warm-up can also improve test reliability (Harman & Pandorf, 2000).

Ratings of perceived exertion (RPE).

Participants were familiarized with the Borg 15-Category Scale for rating perceived exertion (Figure 3.6). Previous research has found that the Borg 15-Category Scale is a valid and reliable instrument for measuring intensity during various strength training exercises (Gearhart et al., 2001; Tiggeman et al., 2010). Participants, therefore, used this scale to rate their perceived exertion (RPE) during the familiarization exercises and throughout each test session. This ensured that all familiarization exercises and cervical strength tests were performed at a safe and appropriate intensity. Furthermore, RPE values given by participants during the familiarization session were used to estimate an appropriate starting weight for the 6-RM neck tests.

According to Gearhart et al. (2001) standardized instructions and methods for use of the Borg-15 category scale can improve the validity of the assessment tool. Therefore, participants were instructed on how to rate perceived exertion according to guidelines established by Gearhart et al. (2001). As recommended, participants were provided with a clear definition of the perception of physical exertion while being presented with the Borg 15-Category Scale. The student researcher explained to participants that "the perception of physical exertion is the subjective intensity of effort or muscular strain that is felt during a resistance exercise" and that the Borg scale is used to translate into numbers feelings of exertion while exercising (Gearhart et al., 2001). Scaling instructions were then outlined for using RPEs during the neck strength exercises. It was explained that the Borg Scale ranges from a minimum score of 6, which represents no exertion at all, to a maximum score of 20, corresponding to maximum muscle exertion. A rating of 7 should represent feelings equivalent to that felt when performing a repetition without any resistance weight added to the Nautilus machine, while a response of 19 would be appropriate when moving maximum weight for neck flexion or extension (Gearhart et al., 2001). Participants were asked to provide a rating of perceived exertion after each working set of the familiarization and test sessions based on the amount of exertion they experienced in their neck muscles. The Borg Scale was placed in full view for participants throughout each test session so that they could easily relate their perceived muscle exertion with the numbers on the scale.

Isometric familiarization.

Participants were positioned within the Nautilus machine according to their height with their head and neck in a designated neutral position. Participants then completed three submaximal isometric efforts of increasing intensity for cervical flexion and extension. Intensity levels included 50%, 75%, and 90% of maximal effort with 2 to 3-minutes of rest provided between each effort. Participants rated their perceived exertion immediately following each effort. During each practice effort participants were supervised by the student researcher and were corrected on form. Technique was monitored as a precautionary measure against injury and to ensure that all participants used consistent form during the maximal isometric testing.

The Borg Scale

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Figure 3.5. Borg 15-Category Scale for rating perceived exertion. Note. From Borg's Perceived Exertion and Pain Scales, p 47, by G. Borg, 1998, Illinois: Human Kinetics.

Isotonic familiarization.

During the isotonic familiarization participants were accustomed to performing cervical flexion and extension exercises using a standardized form. Although a 6-RM test was not completed during this session participants progressed through a series of isotonic neck exercises of increasing weight loads. The normal cervical active range of motion accepted for this study was 42^0 to 83^0 of flexion and 60^0 to 108^0 of extension (Youdas et al., 1992). This range of motion was used for the 6-RM tests in order to standardize movements. Participants, therefore, practiced this range of motion when completing the isotonic familiarization exercises. A Biometrics electrogoniometer, attached to the moveable arm of the Nautilus machine, was used to monitor the range of motion for all cervical movements. Additionally, a metronome was used to control the speed of cervical flexion and extension movements. The cadence was set at 1.5-seconds for each phase (concentric and eccentric) of the movement, so that one repetition was completed per 3-seconds. This ensured that all repetitions were completed at a uniform cadence and that each participant performed the neck exercises at a consistent speed.

Beginning with either cervical flexion or extension participants completed one set of 10 to 12 repetitions at a resistance equal to 5% of their body weight. Following a 2 to 3-minute rest interval participants then performed eight to 10 repetitions of the same movement at a resistance of 10% body weight. After an additional 2 to 3-minutes of recovery participants completed a final set of six to eight repetitions at a resistance of 15% of their body weight. Participants were given a 3 to 5-minute rest period before completing the same series of sets for the opposite direction of movement. Participants rated their perceived exertion following each exercise set. According to the scaling guidelines outlined by Gearhart et al. (2001) expected RPE values were determined for each set of the isotonic familiarization and are presented in Figure 3.7. Although the weight used during each set was based on a percentage of body weight, RPE values were used to monitor the exercise intensity and adjust the resistant weight accordingly. Additionally, RPE values of 15 to 18 are appropriate and were expected when completing the 6-RM tests completed to fatigue. A range of RPE values can be expected for the cervical 6-RM tests as ratings of perceived exertion has been shown to vary according to the training level of the participants (Tiggemann et al., 2010).

Ratings of Perceived Exertion		Workload
6	No exertion at all	
7		Repetition with no weight
8	Extremely light	Set #1 10-12 repetitions at 5% body weight
9	Very light	
10		
11	Light	Set #2 8-10 repetitions at 10% body weight
12		
13	Somewhat hard	Set #3 6-8 repetitions 15% body weight
14		
15	Hard (heavy)	
16		6-RM completed to fatigue
17	Very hard	
18		
19	Extremely hard	
20	Maximal exertion	

Figure 3.6. Expected RPE values for each set of the isotonic familiarization.

Isometric test session.

The following protocol for maximal isometric testing was adapted from that of Burnett, Coleman, and Netto (2008) and Leggett et al. (1991).

1. Participants performed the same prescribed warm-up and dynamic stretching routine as they did at the familiarization session (Appendix F).
2. Each individual was positioned in the Nautilus machine, with the seat adjusted to an appropriate height with his head and neck in the designated neutral position.

3. Participants performed three maximal isometric efforts in either cervical flexion or extension. Each isometric effort was performed in a neutral neck position. Participants began with their head against the resistance pad and increased to maximum force over a 3-second period. Once maximum force was achieved participants were required to hold maximum tension for an additional 2-seconds. A metronome was used to regulate the speed and timing of the isometric contraction. Three minutes of rest was provided between each isometric trial during which participants rated their perceived exertion. Concurrent visual feedback was provided during each contraction on a computer screen that was interfaced with the load cell and the Nautilus machine. Participants were also verbally encouraged to give maximum efforts.
4. The same procedure was repeated for the opposite direction of neck movement following 3 to 5-minutes of recovery.
5. The peak isometric value from the three test trials, for flexion and extension, was used to describe the maximal isometric neck strength of each participant.

Isotonic test session.

The following 6-RM testing protocol for isotonic strength testing was adapted from that of Kraemer, Ratamess, Fry, and French (2002) and Burnett, Coleman, and Netto (2008).

1. Participants performed the same prescribed warm-up and stretching routine as the previous two tests sessions (Appendix F).
2. Each participant was positioned in the Nautilus machine according to height with his head and neck in the designated neutral position.

3. Beginning with flexion or extension participants performed a light isotonic warm-up within the Nautilus machine, consisting of 10 repetitions with 50% of their estimated 6-RM. This resistance was light enough to allow easy completion of set repetitions.
4. Participants were given a 1-minute rest interval.
5. Participants then performed six repetitions at 70% of their estimated 6-RM.
6. Another 1-minute rest interval was provided.
7. Participants repeated the exercise at 90% of the estimated 6-RM for three to six repetitions.
8. After a 3-minute rest interval, participants attempted six repetitions with 100% to 105% of their estimated 6-RM. Data from this set was accepted for predicting 1-RM values if a minimum of four or a maximum of eight repetitions were completed. If a participant completed more or less than this standardized number of repetitions retesting occurred after 24 hours of rest, as fatigue would greatly affect performance on additional sets.
9. Following 5-minutes of recovery the same protocol was used to test the 6-RM for the opposite direction of neck movement.

The cadence of the repetitions was the same as the familiarization session. The metronome was set so that one repetition was completed per 3-seconds. Repetitions were accepted if they were greater than the cervical active range of motion (AROM) described in the isotonic familiarization or up to 10^0 less than the cervical AROM. A repetition was defined as a failed attempt if it was not completed at the appropriate speed or if the range of motion was less than the accepted range. If a participant experienced two failed repetitions within a single set, the test was terminated and if necessary retesting was completed after 24 hours of rest. Verbal encouragement was given throughout the 6-RM protocol.

Safety Precautions & Post-Test Follow-up

Participants were monitored throughout the duration of the study and for at least one week following the last test session. Participants were requested to record the type and duration of any physical activity they participated in outside of the study. Additionally, participants were to note any excessive pain or muscle soreness following a test session or other physical activity. Participants only proceeded in further neck testing once any related muscle soreness had diminished. No further testing was done if a participant was experiencing any type neck pain or excessive muscle fatigue. Participants' perceived exertion and physical conditions were also recorded during each test session. A test session would have been terminated if a participant experienced any pain or unreasonable discomfort. Participants completed a standardized warm-up and dynamic stretching routine at the start of each test session as well as static stretches post testing in order to minimize muscle soreness (Appendix F). Communication was maintained with participants via email and/or telephone for one week following the final test session to ensure there was no residual effect experienced from testing.

Data Analysis

A one-way ANOVA was used to determine if any significant differences existed among the anthropometric data of the three participant groups.

The peak isometric flexion and extension force values were determined from the test trials and were used to describe the maximum isometric neck strength of each participant. Participants' 1-RM neck strength was predicted for cervical flexion and extension by substituting data from the 6-RM tests into the Wathen (1994) equation. In regards to the first research question, a Pearson Product Moment Correlation was conducted to determine what, if any, linear relationships exist between isotonic and isometric neck force. A 3x2x2 mixed factorial ANOVA with repeated measures on the third factor was completed to compare maximal isometric and predicted 1-RM (isotonic) neck force among participant groups. The dependent variable of the ANOVA was neck force, measured in kg/body weight. The three independent variables included muscle contraction type (isometric and isotonic), participant group (wrestlers, hockey players, and controls), and movement direction (flexion and extension). Predictive Analytics Software (PASW) Statistics 18 for Windows was used for all statistical testing

CHAPTER FOUR-RESULTS

Anthropometric Measurements

Anthropometrics were taken for each participant prior to testing and included height, mass, neck length, and neck girth. Individual data is found in Appendix G. Table 4 presents the group mean and standard deviation of each anthropometric measurement and the average age of each participant group. There were no statistically significant differences among the three participant groups in regards to age or anthropometrics.

Table 4

Descriptive Characteristics of Participant Groups

Participant group	Age (yrs)	Height (cm)	Mass (kg)	Neck girth (cm)	Neck length (cm)
Control group (n = 8)	21.3 (± 1.7)	174.2 (± 8.2)	78.7 (± 11.8)	38.3 (± 1.7)	11.6 (± 1.7)
Hockey players (n = 8)	20.8 (± 1.8)	180.9 (± 6.7)	86.6 (± 11.6)	39.0 (± 1.6)	11.9 (± 1.4)
Wrestlers (n = 8)	21.3 (± 2.0)	178.6 (± 9.2)	81.1 (± 16.9)	39.9 (± 2.9)	11.6 (± 1.9)

Values are presented as mean (± SD).

Descriptive Statistics

The mean absolute strength value and standard deviation of each strength test is presented for each participant group in Table 5. The units of measurement are consistent with those used for testing, that is, isometric measurements are in Newtons while isotonic measurements are presented in kilograms. The isotonic strength values represent predicted 1-RM values that were determined using a 6-RM test completed to fatigue and the Wathen (1994) equation. The number of repetitions completed during the attempted 6-RM tests varied between participants and movement direction. Although participants completed, on average, six repetitions (SD = 1.5) when attempting the 6-RM cervical flexion test, the number of repetitions ranged from four to eight. Likewise the number of repetitions completed during the attempted 6-RM cervical extension test ranged from a minimum of four to a maximum of eight. Participants, however, generally performed more repetitions during the extension strength test (M = 7, SD = 1.1).

Table 5

Mean Absolute Strength Values and Standard Deviations of Participant Groups

Participant Group	Isometric flexion (N)	Isometric extension (N)	Isotonic flexion (kg)	Isotonic extension (kg)
Controls	105.8 (± 29.4)	171.5 (± 55.5)	15.5 (± 1.3)	26.5 (± 5.9)
Hockey players	162.9 (± 52.3)	208.6 (± 41.6)	16.4 (± 3.6)	29.0 (± 8.7)
Wrestlers	166.7 (± 49.6)	240.1 (± 69.1)	23.0 (± 5.2)	39.0 (± 4.0)

Values are presented as mean (± SD).

The mean normalized strength values and standard deviations of each participant group are shown in Table 6. The isometric and isotonic flexion and extension values of each participant were divided by his own body weight in order to normalize the data. Participants' absolute and normalized strength values are presented in Appendix H. By normalizing the data isometric and isotonic neck strength could be compared among participant groups, as the units of measurement would be the same for all strength values. Although data sets are presented for both absolute and normalized strength score, statistical analysis was completed using only the mean normalized group data (Table 6).

Table 6

Mean Normalized Strength Values and Standard Deviations of Participant Groups

Participant group	Isometric flexion	Isometric extension	Isotonic flexion	Isotonic extension
Controls	0.14 (± 0.03)	0.21 (± 0.05)	0.20 (± 0.03)	0.34 (± 0.09)
Hockey players	0.19 (± 0.05)	0.25 (± 0.04)	0.19 (± 0.02)	0.33 (± 0.09)
Wrestlers	0.21 (± 0.07)	0.31 (± 0.09)	0.31 (± 0.09)	0.50 (± 0.12)

Values are presented as mean (± SD).

Correlations Between Isotonic and Isometric Neck Strength

A Pearson Product Moment Correlation was conducted in order to determine what, if any, relationships existed between isotonic and isometric neck strength (Table 7). As shown, there was a strong linear relation between flexion and extension movements of the same muscle contraction type ($r_{isotonic} = 0.83$, $r_{isometric} = 0.81$, $p < 0.01$). Therefore, participants' predicted 1-RM flexion scores were strongly related to their predicted 1RM extension scores. Likewise, isometric flexion scores were strongly related to isometric extension scores. Although correlations were shown between isotonic and isometric muscle contractions, the relations were only significant at the 0.05 level for both movement directions. Extension values showed the strongest relation when comparing correlations between the two types of muscle contractions ($r_{extension} = 0.47$, $p < 0.05$). The relation between isotonic flexion and isometric flexion was the same as that between isotonic flexion and isometric extension ($r = 0.45$, $p < 0.05$). Scatterplots displaying the linear correlations are found in Appendix I.

Table 7

Correlations between Isometric & Isotonic Strength Values

	Isometric flexion	**Isometric extension**	**Isotonic flexion**	**Isotonic extension**
Isometric flexion	-			
Isometric extension	0.81**	-		
Isotonic flexion	0.45*	0.45*	-	
Isotonic extension	0.43*	0.47*	0.83**	-

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Main Effects

A mixed factorial ANOVA yielded a main effect for movement direction, F (1, 21) = 174.22, $p < 0.05$, such that the average force produced was significantly higher for neck extension (M = .32, SD = .12) than for neck flexion (M = .20, SD = .07) among all participants. The main effect of muscle contraction type yielded an F ratio of F (1, 21) = 36.29, $p < 0.05$, indicating that the average neck force was significantly greater for isotonic muscle contractions (M = .31, SD = .13) than for isometric muscle contractions (M = .22, SD = .08). Finally, the main effect of participant group yielded an F ratio of F (1, 21) = 10.11, $p < 0.05$, indicating that the mean force produced was dependent on the type of participant performing the neck tests. The mean neck force of the wrestlers (M = .33, SD = .14) was significantly greater than that of the hockey players (M = .24, SD = .08), and the controls (M = .22, SD = .09) ($p < 0.05$). There was no significant difference, however, between the mean neck force of the hockey players and the controls ($p = 0.49$).

Interaction Effects

The interaction effect between muscle contraction type and movement direction was significant, F (1, 21) = 32. 05, $p < 0.05$, indicating that the effect of movement direction was greater when isotonic muscle contractions were performed, F (1, 21) = 128.14, $p < 0.05$, than when isometric neck muscle contractions were performed, F (1, 21) = 64.86, $p < 0.05$. This is illustrated in Figure 4.1. Likewise, the effect of muscle contraction was greater for extension movements than for flexion movements (Figure 4.2).

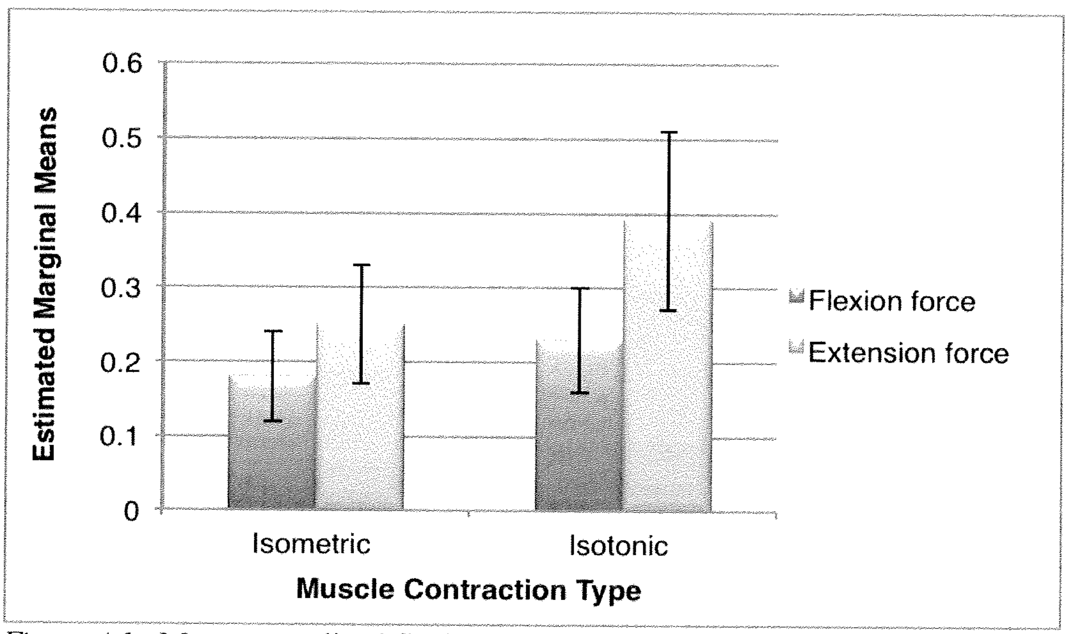


Figure 4.1. Mean normalized flexion and extension force for both muscle contraction types. A significant interaction effect is shown between muscle contraction type and movement direction, indicating the effect of movement direction was greater for isotonic muscle contractions than for isometric muscle contractions.

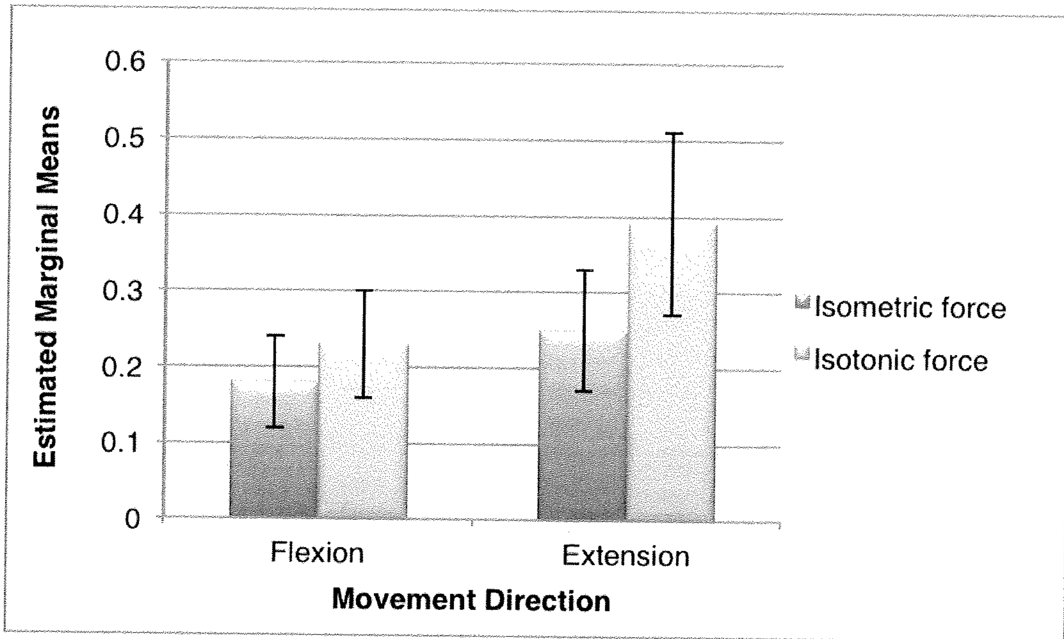


Figure 4.2. Mean normalized isometric and isotonic neck force for each movement direction. The effect of muscle contraction type was greater for extension movements than for flexion movements.

The interaction between participant group and movement direction was non-significant, $\underline{F}$ $(1, 21) = 2.80$, $p > 0.05$, indicating that the effect of movement direction was not conditional upon the participant group. As shown in Figure 4.3, the mean difference between flexion and extension force values did not vary significantly among participant groups.

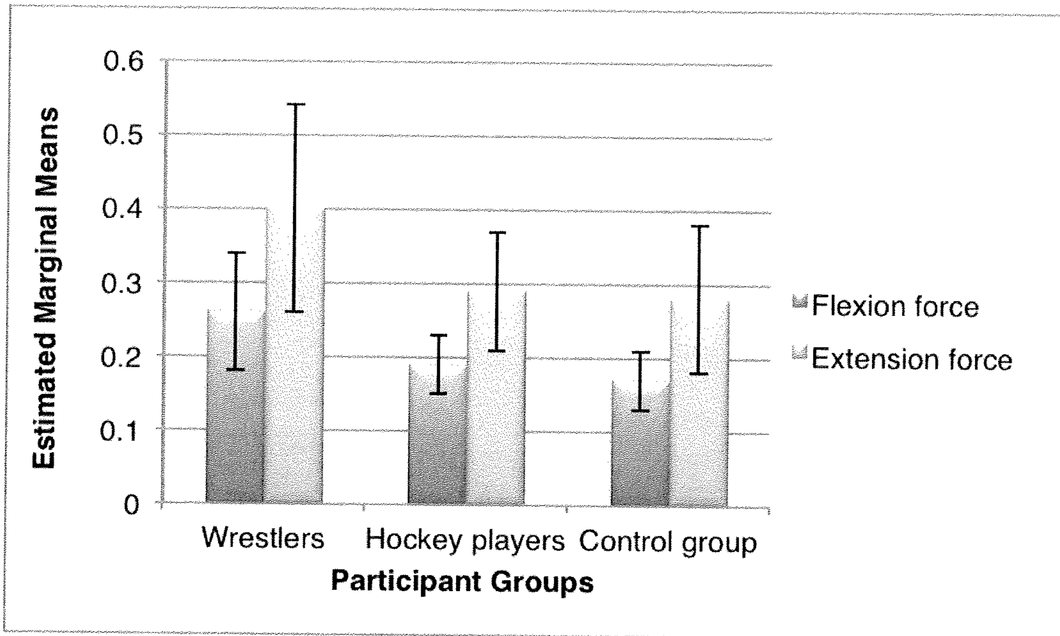


Figure 4.3. Mean normalized cervical flexion and extension force of each participant group. The effect of movement direction was not conditional upon participant type.

The interaction between participant group and muscle contraction was also non-significant, F (1, 21) = 3.26, $p > 0.05$, indicating that the effect of muscle contraction was not conditional upon participant group. Although the mean difference between isometric and isotonic force values varies somewhat among participant groups (Figure 4.4), it was not enough to be statistically significant. As this interaction effect is approaching significance ($p = 0.06$) this result may be attributed to small sample size.

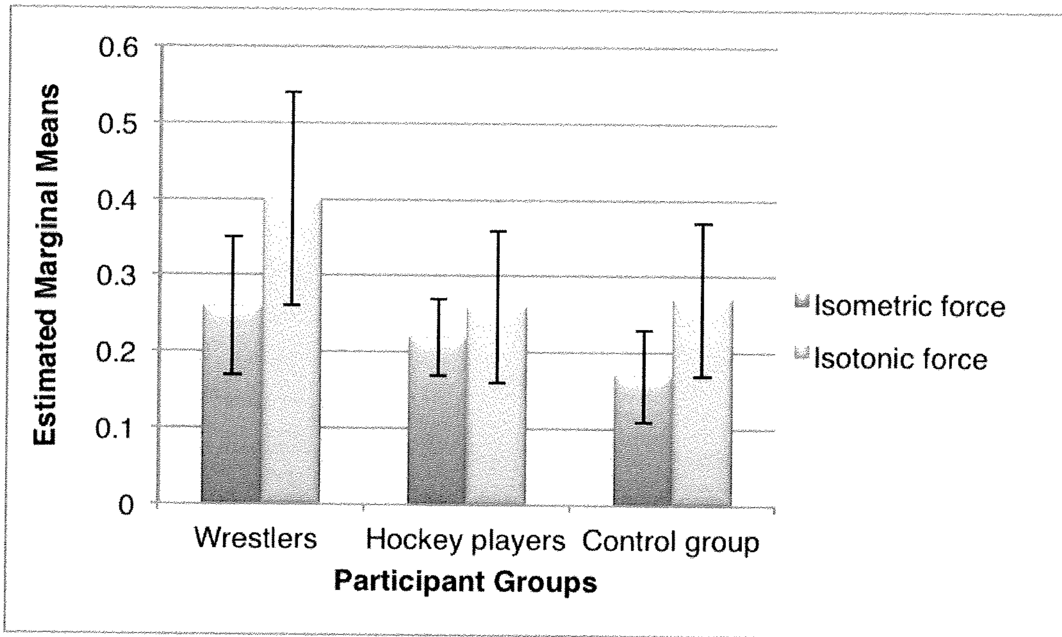


Figure 4.4. Mean normalized isometric and isotonic neck force of each participant group. The effect of muscle contraction type was not conditional on participant type.

The three way interaction effect yielded an F ratio of F (1, 21) = .500, $p > 0.05$, indicating that the interaction effect between contraction type and movement direction was not significantly different among participant groups.

Between Group Comparisons

Common among participant groups, mean normalized cervical extension force was significantly greater than mean flexion force (Figure 4.3). The wrestlers, however, demonstrated the greatest difference between mean neck flexion (M = .26, SD = .08) and mean extension force (M = .40, SD = .14) with an F ratio of F (1, 21) = 90.95, $p < 0.05$. The controls had a mean flexion force of M = .17 (SD = .04) and a mean extension force M = .28 (SD = .10), yielding an F ratio of F (1, 21) = 47.27, $p < 0.05$. The hockey players showed the least difference between mean neck flexion (M = .19, SD = .04) and mean extension force (M = .29, SD = .08) with an F ratio of F (1, 21) = 41.59, $p < 0.05$.

When comparing the mean difference between contraction types the wrestlers also yielded the highest F ratio of $F\ (1, 21) = 26.21, p < 0.05$. Therefore, the mean isotonic neck force was significantly greater than the mean isometric neck force for the wrestlers as it was for the controls, $F\ (1, 21) = 14.23, p < 0.05$. There was no significant difference between the mean isotonic and the mean isometric neck force of the hockey players, $F\ (1, 21) = 2.38, p > 0.05$ (Figure 4.4)

In terms of normalized isometric neck strength the wrestlers yielded the greatest values for both flexion ($M = .21$, $SD = .07$) and extension ($M = .31$, $SD = .09$) movements (Figure 4.5). The hockey players followed with a mean flexion value of .19 ($SD = .05$) and a mean extension value of .25 ($SD = .04$). The control group had the lowest isometric neck strength for both flexion ($M = .14$, $SD = .03$) and extension ($M = .21$, $SD = .05$) movements. The wrestlers and the hockey players were both significantly stronger than the control group in regards to normalized isometric flexion strength, ($p = .005$) and ($p = .037$), respectively. There was no significant difference, however, between the isometric flexion strength of the wrestlers and the hockey players ($p = .373$). Likewise, there was no significant difference between the normalized isometric extension strength of the wrestlers and the hockey players ($p = .094$). Although the wrestlers were significantly stronger than the control group ($p = .008$), there was no significant difference between the isometric extension strength of the hockey players and the control group ($p = .246$).

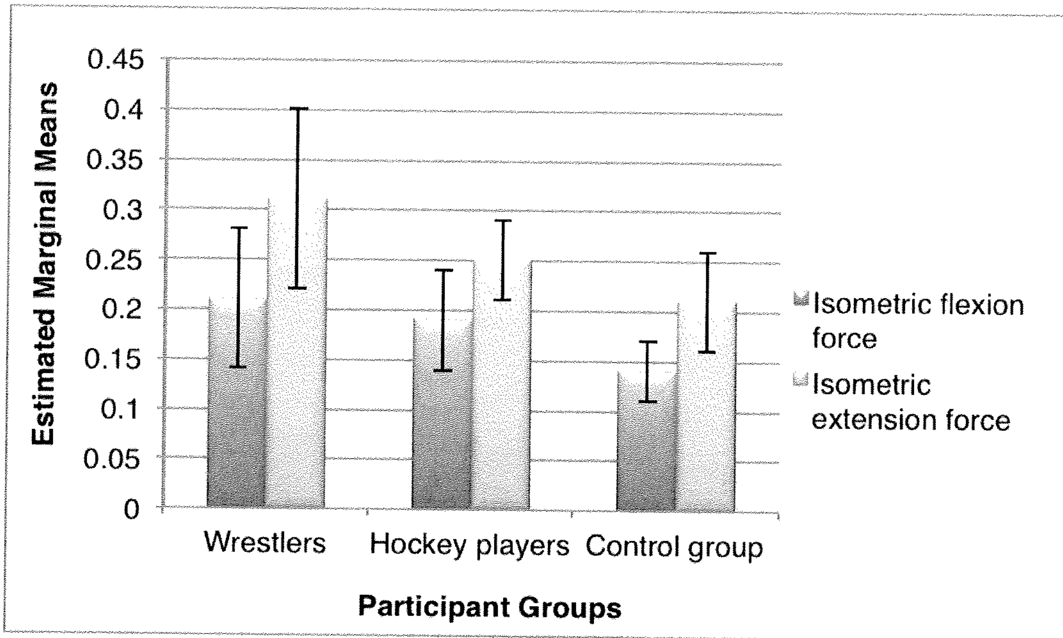


Figure 4.5. Mean normalized flexion and extension force for each participant group during isometric muscle contractions.

Trends resulting from isotonic strength testing were comparatively different than the isometric cervical strength patterns. Although the wrestlers continued to have the greatest force for isotonic neck flexion ($M = .31$, $SD = .09$) and extension ($M = .50$, $SD = .12$), the normalized strength values of the control group were greater than those of the hockey players for both neck flexion and extension tests (Figure 4.6). The mean difference between the normalized isotonic force of the control group and hockey players, however, was non-significant for either flexion ($p = .646$) or extension ($p = .822$) movements. Isotonic neck strength of the wrestlers was significantly greater than that of the hockey players for flexion ($p = .001$) and extension ($p = .003$). As well, the wrestlers were significantly stronger than the control group in terms of normalized isotonic neck flexion ($p = .003$) and extension ($p = .004$).

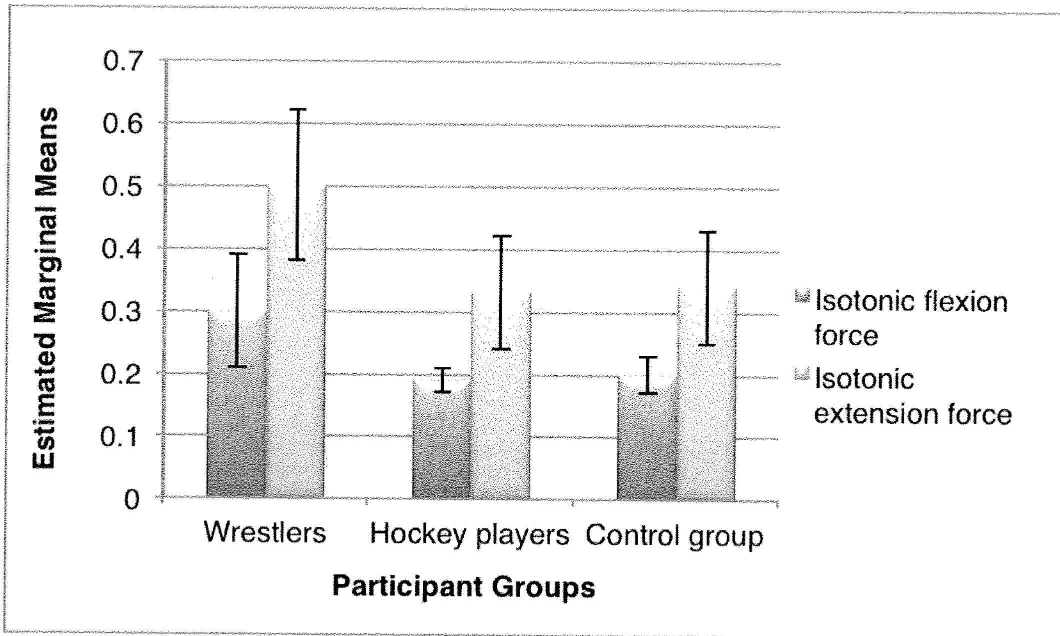


Figure 4.6. Mean normalized flexion and extension force of each participant group for isotonic muscle contractions.

Within Group Comparisons

Statistical characteristics and interaction effects differed within each participant group.

Wrestlers.

The wrestlers' isotonic neck force was significantly greater than their isometric neck force for both flexion, $\underline{F}$ (1, 21) =14.04, $p < 0.05$ (Figure 4.7), and extension movements, $\underline{F}$ (1, 21) = 27.52, $p < 0.05$ (Figure 4.8). These F ratios also indicate that the effect of muscle contraction type was greater when extension movements were performed than when flexion movements were performed. Additionally, extension force was significantly greater than flexion force for both isometric muscle contractions, $\underline{F}$ (1, 21) = 34.748, $p < 0.05$ (Figure 4.5), as well as isotonic muscle contractions, $\underline{F}$ (1, 21) = 66.131, $p < 0.05$ (Figure 4.6). The effect of movement direction was greater when isotonic muscle contractions were performed than when isometric muscle contractions were performed.

Control group.

Similar to the wrestlers, the isotonic neck force of the control group was significantly greater than the isometric neck force for both flexion, $F\ (1, 21) = 8.94$, $p < 0.05$, and extension movements, $F\ (1, 21) = 13.92$, $p < 0.05$ (Figure 4.7 & 4.8). Again, the effect of muscle contraction type was greater during extension movements than during flexion movements. Cervical extension force was also significantly greater than flexion force for both isometric neck contractions, $F\ (1, 21) = 20.35$, $p < 0.05$ and isotonic muscle contractions, $F\ (1, 21) = 32.49$, $p < 0.05$ (Figure 4.5 & 4.6). The F ratios also indicate that the effect of movement direction was greater when isotonic muscle contractions were performed than when isometric muscle contractions were performed.

Hockey players.

The isotonic neck force of the hockey players was significantly greater than the isometric force for extension movements only, $F\ (1, 21) = 5.46$, $p < 0.05$ (Figure 4.8). There was no significant difference between isotonic and isometric flexion forces, $F\ (1, 21) = .024$, $p > 0.05$ (Figure 4.7). Like the other two participant groups, the hockey players' cervical extension force was significantly greater than their flexion force for both isometric contractions, $F\ (1, 21) = 12.56$, $p < 0.05$ and isotonic contractions, $F\ (1, 21) = 33.35$, $p < 0.05$.

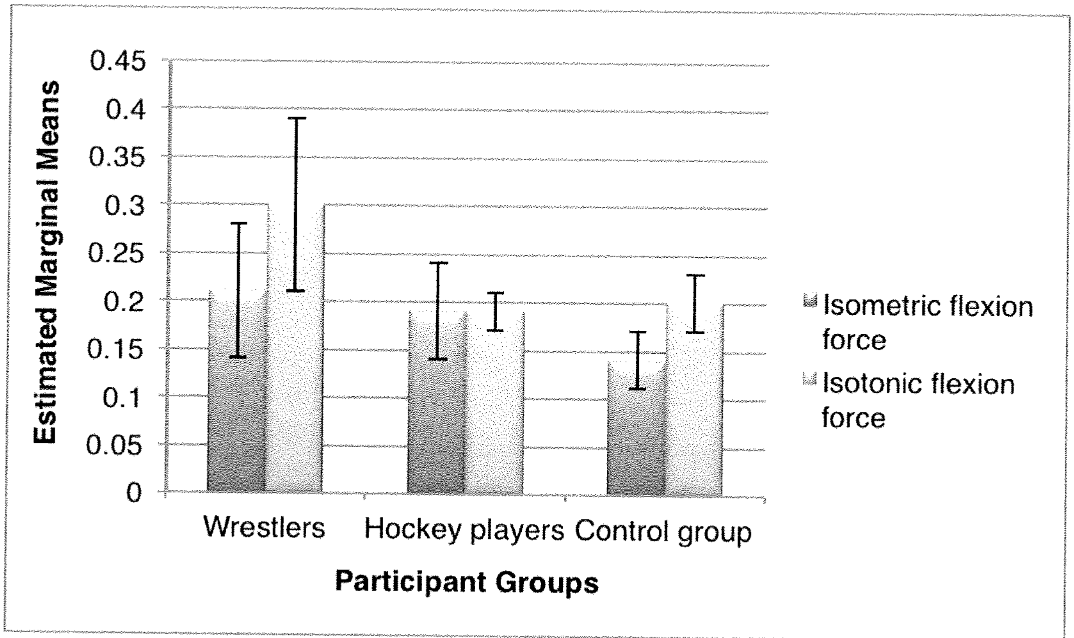


Figure 4.7. Mean normalized isotonic and isometric neck force of each participant group for flexion movements.

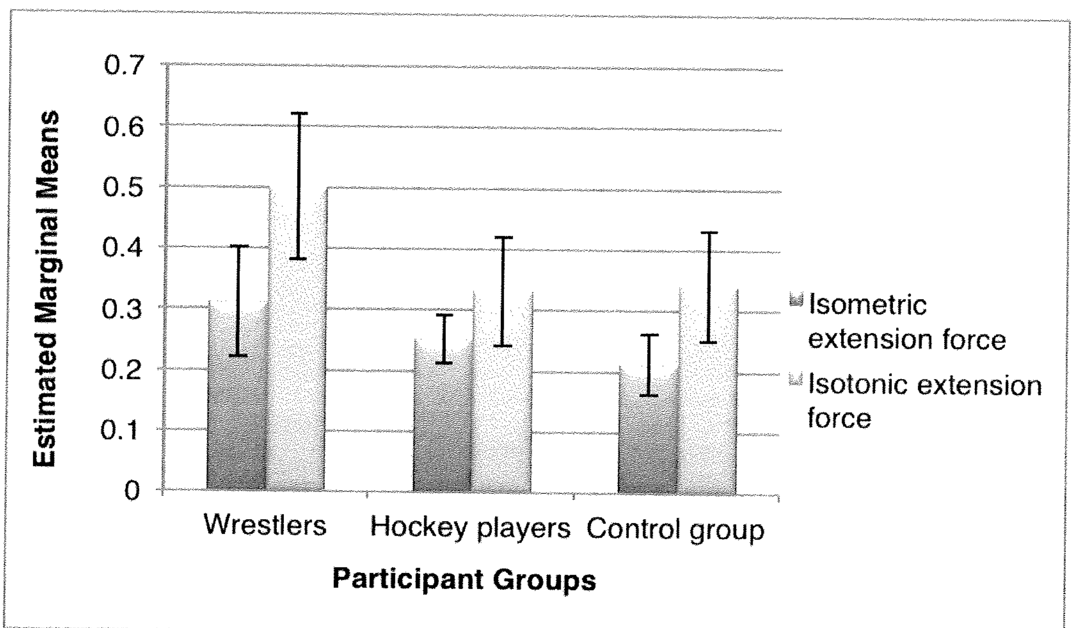


Figure 4.8. Mean normalized isotonic and isometric neck force of each participant group for extension movements.

CHAPTER FIVE-DISCUSSION

Throughout the literature it is recommended that athletes involved in contact sport include strengthening exercises for the cervical musculature within their training programs in order to reduce the risk and severity of neck injuries and improve sport performance (Cross & Serenelli, 2003; Tator, Carson, & Cushman, 2000; Tator & Edmonds, 1984; Wroble & Albright, 1986). Resistance training of the cervical spine can enhance an athlete's ability to effectively stabilize the neck, while developing reflex systems and proprioceptive awareness, all of which are factors that contribute to injury prevention and improved body mechanics. In addition, an increase in contractile forces of the neck may improve the ability of the neck muscles to absorb external forces. Various studies that have evaluated cervical strength and neck training programs found that neck specific, isotonic resistance exercises were most beneficial to improving neck muscle size, strength, and the functional capabilities related to contact sport (Conley, Stone, Nimmons, & Dudley, 1997; Cross & Serenelli, 2003; Leggert et al., 1991; Ylinen et al., 2009).

Hockey players and wrestlers were included for cervical strength testing in the present study as both athletes play a contact sport in which specific trends in neck injuries have been observed. Furthermore, there is a considerable difference in the cervical strength training that is commonly followed by each type of athlete. In surveying some of the present hockey programs, ranging from amateur to varsity and even professional levels, very few include specific neck strengthening exercises. Wrestlers, however, regularly perform cervical strengthening exercises, consisting of both dynamic and static muscle contractions (Grindstaff & Potach, 2006; Ylinen et al., 2003). The cervical strength of third and fourth year kinesiology students was also assessed for comparative purposes. Kinesiology students served as a control group as these students typically engage in recreational sport or physical activity and nonspecific training. Therefore, a comparison of static and dynamic neck strength among these three participant groups, may demonstrate how the specificity, intensity and frequency of resistance training programs influence cervical muscle strength.

Although statistically significant, the linear relation between isometric and isotonic cervical strength measurements was low for both cervical flexion ($r = 0.45$) and extension movements ($r = 0.47$). Therefore, participants that exhibited superior isometric neck strength did not necessarily demonstrate great isotonic neck strength and vice versa. A stronger linear relationship was seen between flexion and extension force measurements of the same contraction type ($r_{isotonic} = 0.83$; $r_{isometric} = 0.81$). Participants that performed well on the predicted 1-RM flexion test also did well on the predicted 1-RM extension test. Likewise, participants that produced greater isometric force for flexion movements did so for isometric extension movements as well. The fact that strength values were more strongly related when neck movements were of the same contraction type, suggests that cervical strength measurements are specific to the mode of testing.

Despite the fact that no other study has examined the relation between isometric and isotonic neck strength, the present findings are consistent with previous literature. Baker, Wilson, and Carlyon (1993) also found low correlations between isometric and dynamic strength measures of both the lower body ($r = 0.57$) and upper body ($r = 0.57$). Similarly, Moss and Wright (1993) reported that isometric, isotonic and isokinetic methods of assessing knee strength produced significantly different absolute strength values. According to both studies, the low relationship between isometric and dynamic strength values indicates that strength measurements are specific to the test modality and that results of different measurement techniques should not be generalized from one to another (Baker, Wilson, & Carlyon, 1993; Moss & Wright, 1993).

Although isometric strength tests are useful for assessing isometric neck strength they cannot be used to accurately assess isotonic neck strength. Furthermore, weaknesses in dynamic neck strength cannot properly be identified from isometric neck assessments.

Additionally Baker, Wilson, & Carlyon (1993) found that changes in isometric and isotonic strength, following 12 weeks of resistance training, were unrelated for both the lower ($r = 0.16$) and upper body ($r = 0.12$). This indicates that isotonic and isometric muscular adaptations differ in response to isotonic training. As Murphy and Wilson (1996) explained, both types of muscle contractions involve specific, but dissimilar motor unit recruitment patterns, which result in differing force outputs. Consequently, isometric cervical force tests are not valid for monitoring the neuromuscular adaptations that are induced through dynamic training (Baker, Wilson, & Carlyon, 1993). Therefore, the results of the present study are in agreement with previous literature in that the conditions used for assessing muscular performance should be specific to the training program (Kraemer, Ratamess, Fry, & French, 2006). If athletes are prescribed an isotonic cervical strength training program, isotonic testing should be used to monitor progress.

In comparing anthropometrics, there were no significant differences among the participant groups ($p > 0.05$). Similarly, Ylinen et al. (2003) found non-significant differences among participants when they compared the anthropometrics of senior and junior wrestlers with untrained controls. Despite similar anthropometrics, the mean normalized neck force of the wrestlers in the current study was significantly greater than that of the other two participant groups ($p < 0.05$). Since differences in cervical strength were not related to body size the superior neck force of the wrestlers may be attributed to their cervical strengthening program. These results also suggest that the wrestler's cervical training elicits increases in neck strength that are greater than gains in muscle hypertrophy. This is in agreement with the findings of Conley, Stone, Nimmons, and Dudley (1997b), in which 12 weeks of neck extension resistance training resulted in a 13% increase in total neck muscle cross-sectional area while cervical extension strength (3 x 10-RM) increased by 34%. According to Gabriel, Kamen, and Frost (2006) these observations are evidence of neural adaptations to resistance training. In a previous study Conley, Stone, Nimmons, and Dudley (1997a) suggested that neural adaptations, including increased muscle activation and desynchronization of motor unit firing, would likely reduce the severity of cervical injury by enabling greater force development and delaying muscle fatigue. Such neuromuscular adaptations, however, were evoked only when specific cervical exercises were performed (Conley, Stone, Nimmons, & Dudley, 1997a). Therefore, results of the current research support the recommendations of previous literature regarding cervical strength training for neck injury prevention and increased sport performance.

The mean normalized neck force was significantly greater for isotonic muscle contractions than for isometric contractions, ($p < 0.05$). In a comparable study involving isometric and isotonic lower body strength testing, Blazevich, Gill, and Newton, (2002) reported that on average, isometric squat lifts were 147% of the 1-RM lifts, while isometric front hack squat lifts were 89% of the respective 1-RM. Although Moss and Wright (1993) found knee isometric flexion and extension measurements to be greater than corresponding isotonic strength measures, inconsistencies were reported as to how the different strengths were measured. Therefore, isometric and isotonic strength values may differ depending on the type of equipment and testing procedures used and the specific muscles that are tested. Nevertheless, it may be beneficial for athletes in contact sport to focus on isotonic neck resistance exercises as the results of the present study suggest that isotonic neck muscle contractions elicit greater contractile forces than isometric contractions. As discussed previously, greater contractile force may play a substantial role in neck injury prevention and athletic performance. Additionally, the dynamic movement and muscular contractions involved in isotonic training are consistent with the neuromuscular activity used during sport competition. In accordance with the specificity of training principle it is important that the neck muscle action utilized in training mimic that which is predominantly used in competition in order to maximize training outcomes (Conley, Stone, Nimmons, & Dudley, 1997b).

Unique differences were found in the normalized isotonic and isometric neck strengths among participant groups. The wrestlers' isotonic neck force was significantly greater than their isometric neck force for flexion and extension movements, ($p < 0.05$). The same was true for the controls. The hockey players, however, showed little difference between isotonic and isometric neck strength. The isotonic neck force of the hockey players was significantly greater than the isometric force for extension movements only ($p < 0.05$). Additionally, the wrestlers' normalized isotonic neck force was significantly greater than that of the hockey players and the controls, for flexion and extension movements ($p < 0.05$). There was no significant difference, however, in isotonic neck force between the hockey players and the controls for either flexion or extension movements ($p > 0.05$). As no other study has examined the isometric and isotonic neck strength of various athletes, it is difficult to compare the present data to that of previous research. Although the isometric force values of the wrestlers in this study are less than those reported by Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, and Ylinen (2005) and Ylinen et al. (2003), differences in testing equipment and population groups would likely attribute to the variations in strength values. No study was found that measured the isotonic neck force of wrestlers or the cervical strength of hockey players. Likewise, as the literature does not include any data related to 1-RM testing of the cervical muscles, the predicted 1-RM values reported in this study could not be compared to those of other investigations. Nevertheless the comparisons of neck force, as described above, further demonstrate the wrestlers' superior isotonic neck strength in relation to that of the hockey players. Previous literature suggests that the enhanced isotonic neck force of the wrestlers is related to exercise intensity and muscle recruitment patterns that are developed through specific strength training (Burnett, Coleman, & Netto, 2008; Burnett, Naumann, Price, & Saunders, 2005).

In comparing two isotonic cervical training modalities, including a pin-loaded machine and Thera-Band tubing, Burnett, Naumann, Price, and Saunders (2005) proposed that the pin-loaded machine was more effective for increasing isometric neck strength. Furthermore, Burnett, Coleman, and Netto (2008), reported that the Thera-Bands were associated with significantly lower EMG activations than a pin-loaded machine, which would explain the lower training effect produced by the Thera-Bands. Although isotonic neck strength was not tested in either study, results suggest that the increased intensity of isotonic exercises will generate greater muscle activation, thereby, develop greater cervical muscle strength. Additionally, Murphy and Wilson (1996) found that motor unit activation patterns were significantly different between isometric and dynamic movement. Therefore, the greater isotonic neck strength demonstrated by the wrestlers in the present study is likely related to more intense isotonic neck actions involved in training and competition as compared to the hockey players. By incorporating dynamic cervical exercises into their training, the wrestlers may have developed neural activation patterns specific to isotonic muscle contractions, which may promote increased isotonic neck force.

In terms of normalized isometric neck force, the wrestlers yielded the greatest values for both flexion and extension movements, followed by the hockey players and then the controls.

Although the wrestlers and the hockey players were both significantly stronger than the controls in regards to isometric flexion force, there was no significant difference in isometric flexion force between the two groups of athletes. Likewise, there was no significant difference in isometric extension force between the wrestlers and the hockey players, or between the hockey players and the controls ($p > 0.05$). The wrestlers, however, were significantly stronger than the controls in isometric extension strength ($p < 0.05$). When comparing the isometric cervical strength of elite wrestlers to that of a control group, Rezasoltani, Ahmadi, Nehzate-Koshroh, Forohideh, and Ylinen (2005), also found that isometric cervical flexion and extension strengths were significantly greater in the wrestlers. The investigators attributed the differences in cervical muscle performance to the long-term specific training and competition program followed by the wrestlers (Rezasoltani, Ahmadi, Nehzate-Koshroh, Forohideh, and Ylinen, 2005). As no other significant differences were found between participants in the present study, the contrasts in isometric and isotonic neck strength may be associated with the demands of each athlete's respective sport and their sport specific training.

As Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, and Ylinen (2005) explained, a variety of techniques and maneuvers used in wrestling place excessive loads on the wrestler's cervical spine. For instance, a bridge position in which the back and neck are maintained in an arched position may be used as either an offensive or defensive strategy. Other contortions of the spine and neck, as well as repetitive pulling and pushing movements, are also used for controlling takedowns and pinning the opponent. Such maneuvers require superior spinal and cervical strength. Additionally, stability of the cervical spine must be maintained by active co-contraction of neck extensor and flexor muscles to avoid injury (Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, & Ylinen, 2005). Therefore, to develop both dynamic and static cervical muscle strength wrestlers routinely include neck specific exercises in their training program, consisting of front and back neck bridging, manual resistance and nautilus exercises (Grindstaff & Potach, 2006).

In ice hockey, isometric cervical muscle contractions are consistently used to maintain appropriate head and neck positioning during play. Additionally, most hockey conditioning programs consist mainly of conventional resistance exercises, without any neck specific training. According to Conley, Stone, Nimmons, and Dudley (1997b) conventional resistance exercises elicit forceful isometric contractions of the cervical musculature for stabilization. Although Conley et al. (1997b) reported that the stimulus is insufficient to generate neck muscle hypertrophy or improve isotonic cervical strength it may be enough to increase isometric strength. Therefore, the emphasis placed on isometric contractions of the neck musculature during hockey games, practices, and training may explain why the isometric neck strength of the hockey players did not differ significantly from that of the wrestlers. The lack of neck specific training associated with the hockey players, however, would account for the higher isometric strength and the significantly greater isotonic force measurements still exhibited by the wrestlers.

The physical demands of the respective sports and the differences in cervical strength profiles of the wrestlers and hockey players may also be associated with specific trends in neck injuries observed within each sport. Research shows that there is an increased risk of catastrophic spine injury associated with ice hockey, typically resulting from a headfirst impact into the boards or another player. These situations can cause axial loading to the cervical spine in which the resultant injury is commonly a fracture-dislocation or burst injury at the fifth and/or sixth cervical vertebra (Tator, Carson, & Cushman, 2000). Depending on the force and direction of the impact the severity of this injury can range from a mild concussion to complete paralysis.

Contracting the cervical extensor muscles in order to achieve a head up position prior to impact, however, can avoid axial loading and is therefore, critical to reducing the severity of the resulting injury (Cross & Serenelli, 2003). In other instances, such as those involving board collisions or body checking, appropriate neck muscle tension can reduce head acceleration and enhance the ability of the neck muscles to absorb forces (Tierney et al., 2005). As Tierney et al. (2005) explained such actions could minimize the risk and severity of concussion and whiplash injuries, also common to ice hockey. In contrast to hockey, catastrophic neck injuries in wrestling are rare (Wroble & Albright, 1986; Halloran, 2008). Instead, overuse injuries to the cervical muscles and ligaments are much more prominent, typically resulting from repetitive force overload or excessive training (Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, & Ylinen, 2005). It is plausible that the low incidence of catastrophic neck injuries in wrestling is partly due to the specific neck strengthening exercises that are emphasized in training.

The attention that hockey players place on conventional resistance training may contribute to the variations observed when comparing the isometric neck strength of the hockey players with the controls. Although isometric flexion strength was significantly greater for the hockey players than the controls, isometric extension strength did not differ significantly between these participant groups. Ylinen et al. (2003) also found that while isometric extension strength did not differ significantly between senior and junior wrestlers, the senior wrestlers demonstrated significantly stronger isometric neck strength for flexion and rotation. Ylinen et al. (2003) attributed this muscular strength imbalance to intensity and length of training as the senior wrestlers trained an average of five years longer than the juniors. As the controls of the current study were third and fourth year kinesiology students involved in recreational sport and physical activity, it was assumed that these participants train less intensely and less frequently than the hockey players. Evidence from participants' logbooks supports this assumption. In general, the hockey players played a minimum of two games and attended three to four on-ice practices each week. Additionally, many players took part in off-ice training sessions four to five times per week, consisting mainly of conventional strength and stability exercises. The training programs followed by the hockey players were consistent and routine with practices and workouts usually scheduled at the same time of day. Most of the kinesiology students recorded regular workouts, also consisting of conventional strength exercises in addition to moderate intensity cardiovascular activities. In comparison to the hockey players, however, the training schedules of the controls were generally less consistent and lower in frequency and volume. Information provided by participants, in the logbooks and during test sessions, indicated that none of the hockey players or controls performed neck specific exercises during workouts or practices. As conventional resistance exercises are likely to elicit forceful isometric cervical muscle contractions an increase in training intensity and frequency should further promote neuromuscular activity within the neck, resulting in greater neck strength (Conley, Stone, Nimmons, & Dudley, 1997b).

Findings of the current study are, therefore, consistent with those of Ylinen et al (2003) in that an increase in training intensity appears to improve isometric cervical flexion strength more so than extension strength. Berg, Berggren, and Tesch (1994) also found that after eight weeks of isometric cervical resistance training participants' neck flexion strength increased by 27% while their neck extension strength only increased by 19%. This may explain why the hockey players were significantly stronger than the controls in terms of isometric neck flexion strength, but not in isometric extension strength. The substantial training response of the cervical flexors in combination with the intensity of the hockey players training also explains why there was no significant difference between isometric and isotonic cervical flexion force of the hockey players, while a significant difference was observed between these values for the controls. Additionally, the hockey players demonstrated the least difference between neck flexion and extension force values. Although the cervical flexors appear to respond more favourably to training in terms of isometric strength, no study has monitored the effects of training using isotonic strength testing modalities. Further research is needed to determine the training response of the cervical muscles in relation to isotonic neck strength.

When comparing ratios between cervical isometric flexion and extension strength, Ylinen at al. (2003) also associated the substantial ratios of the wrestlers to the enhanced training response of the cervical flexors. Isometric extension strength was almost twice as high as flexion strength in the non-athletes, while the mean ratio between cervical flexion and extension strength was significantly greater in the more trained groups (Ylinen et al., 2003). The senior wrestlers demonstrated the greatest mean ratio between cervical flexion and extension strength (0.74), while that of the junior wrestlers was slightly less (0.65). Results of the current investigation were similar in that the controls had the lowest ratio of isometric flexion to extension force (0.67). Although the ratio of the wrestlers (0.68) was slightly greater than the control group, the hockey players demonstrated the highest ratio (0.76). As the previous study only measured the isometric neck strength of wrestlers and controls, the ratio of the hockey players cannot be compared. However, in examining the ratios of the various wrestling groups, it may be assumed that the wrestlers in the current study had similar training experience to the junior wrestlers in the study by Ylinen et al. (2003). The mean ratio between isotonic flexion and extension force did not differ between the hockey players and the controls (0.58), while the wrestlers had the highest ratio (0.62). This may further support the notion that while conventional resistance training programs may increase cervical isometric strength, a neck specific training program is necessary for improved isotonic strength.

The main effect for movement direction indicated that the average normalized neck force produced by participants was significantly greater for extension than for flexion movements ($p < 0.05$). This trend was consistent throughout the study regardless of the type of muscle contraction that was performed or the participant group that was tested. Greater cervical extension strength is continuously reported throughout the literature (Berg, Berggren, & Tesch, 1994; Suryanarayana & Kumar, 2004). Suryanarayana and Kumar (2004) explained that larger extension strength reflects the postural role of extensor musculature as well as the muscle mass difference between posterior and anterior muscles of the neck. Improving the ratio of cervical flexion to cervical extension strength of an athlete, however, may be important to reducing neck injury. A low strength ratio may reveal weak cervical muscle groups and significant neck muscle imbalances may reduce spinal stability and predispose an athlete to cervical injury (Ylinen at al. 2003). As Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, and Ylinen (2005) explained, the higher ratio of isometric cervical flexion strength to isometric cervical extension strength suggests that wrestlers have better cervical spine stability than less trained individuals. Ylinen et al. (2003) agree that poor or unbalanced neck muscle strength can be a risk factor for neck injuries in sports that put a great strain on the cervical muscles. Wrestlers endure neck muscle strain consistently throughout a match as their bodies are contorted and necks are held in awkward positions, which is why so much emphasis is place on balanced neck muscle strength. Perhaps not as obvious, the need for balanced cervical strength and proper neck muscle functioning is just as significant in hockey, especially at times of impact or during moments of instability. Although neck injuries can occur in any direction of movement those most relevant to contact sport are cervical flexion and extension injuries. A flexion injury typically involves a sudden deceleration of the body as would occur when a force is delivered to the front of a player during forward movement (Proctor & Cantu, 2000). In this instance the head continues to accelerate forward causing varying degrees of compression injuries depending on the force of the impact. A cervical extension injury occurs when the body is accelerated forward from a push or check from behind, resulting in hyperextension of the neck. Developing a balanced ratio of cervical flexion to extension strength can increase muscle stiffness, which improves the ability of the cervical spine to resist movement and absorb external forces.

CHAPTER SIX-CONCLUSIONS

There were two main objectives to this study. The first was to examine the relation between maximal isometric neck force and predictive 1-RM cervical strength values, for neck flexion and extension. Correlations between isometric and isotonic strength values would confirm whether specific measures of muscle function are required, or if various muscle capabilities can be generalized from a single cervical strength test. Secondly, this study aimed to compare the maximal isometric and predicted 1-RM neck strength values among hockey players, wrestlers, and a control group. Identifying similarities and differences in the cervical strength profiles among athletes may provide insight into the training effects of the cervical muscles, which would be valuable towards neck injury prevention and improved sport performance.

The linear correlation shown between normalized isometric and isotonic cervical strength values indicates that cervical strength measurements are specific to the test modality and that results of different measurement techniques should not be generalized from one form of testing to another. Although isometric neck tests may be used for assessing isometric cervical strength, isotonic tests should be used to evaluate dynamic neck strength and monitor isotonic cervical strength training programs. Evaluating isotonic neck strength may also reveal neck muscle imbalances that can reduce cervical stability and predispose athletes to neck injury.

The wrestlers were found to be significantly stronger than the hockey players in terms of normalized isotonic neck strength, yet no significant differences were found in normalized isometric neck strength between the hockey players and the wrestlers. Wrestlers were also significantly stronger than the controls in terms of normalized isometric and isotonic neck force for both flexion and extension movements. The hockey players, however, were significantly stronger than the controls in normalized isometric flexion strength only. In regards to normalized isometric extension and all isotonic movements there was no significant difference in neck force values between the hockey players and the controls.

Limitations

Results indicate that using the Nautilus machine to complete a submaximal 6-RM test to fatigue may be a safe and effective method of predicting athletes' 1-RM for cervical flexion and extension as a means of assessing isotonic neck strength. Although previous research has shown that submaximal tests completed to fatigue can estimate the 1-RM of various muscle groups with moderate accuracy, no study has used a predictive 1-RM test to evaluate isotonic neck strength (Braith, Graves, Leggett, & Pollock, 1993; LeSuer, McCormick, Mayhew, Wasserstein, & Arnold, 1997). Furthermore, no study was found that used the Nautilus machine to examine isometric or isotonic cervical strength and neck muscle functioning. For these reasons it is difficult to compare the cervical strength values of this study to those of previous research. An additional limitation to this study is that an absolute 1-RM test is difficult to complete due to the vulnerability of the cervical spine and, therefore, evaluating the validity of a predicted 1-RM neck test may be challenging. Continued research into neck strength testing, however, would assist investigators in modifying test equipment while highlighting the necessary precautions that may enable an absolute 1-RM neck test to be completed.

Another limitation was the limited number of participants available for testing. Larger participant groups would provide a better representation of the population and would strengthen statistical data by minimizing the possibilities of committing a type I, or type II error. Determining a more ideal testing period for athletes may promote participation. The testing period of the present study occurred during the regular competition season of both the wrestlers and the hockey players. This limited the time that players were available for testing and likely resulted in fewer athletes volunteering. As test sessions were scheduled around athletes' competitions, training, and practices the time between test sessions was also extended for some participants.

It is questionable whether participants' training schedules had an effect on their cervical strength values. The logbooks that participants were requested to keep throughout the duration of the study supported the researcher's assumptions regarding typical training routines. While the athletes mainly participated in sports specific training and team practices, the kinesiology students were mostly engaged in recreational activities and conventional weight training exercises. As participants were not asked to refrain from any type of exercise prior to testing, it is possible that such training and physical activities could have impacted test results. However, muscle soreness and fatigue was also monitored and participants did not proceed with further testing if any significant muscle discomfort was indicated, whether it was caused from testing or from other activities. Furthermore, a practical application of this study is to use the testing equipment and procedures to assess cervical muscle strength and functioning throughout an athlete's training program. Therefore, having participants continue their typical training routines during the testing period would provide realistic results. Nevertheless, it may be beneficial to examine the athletes' cervical strength during in-season and off-season training.

Delimitations

The results of this study are delimited to the participant groups that were used for testing. This includes male varsity wrestlers, male varsity and junior level hockey players, and male kinesiology students. Findings are also delimited to the equipment used for testing, that is, the Nautilus neck strengthening machine. Furthermore, the 1-RM cervical flexion and extension values in this study were predicted using only the Wathen (1994) equation and a 6-RM submaximal test. Finally, participants' neck strength profiles were described in terms of maximal isometric and predicted 1-RM cervical flexion and extension values. Neck injuries most significant to contact sport are typically those involving hyper-flexion, hyperextension, and axial loading of the cervical spine (Proctor & Cantu, 2000). This study, therefore, focused on cervical flexor and extensor strength, as these are the primary muscle groups involved in injury mechanisms related to sport. Including lateral flexion and rotational strength, however, may provide a more comprehensive neck strength profile.

Recommendations

Results of this study confirm that it is beneficial for athletes in any contact sport to include both isometric and isotonic cervical strengthening exercises within their training programs. Although studies have examined the isometric cervical strength profiles of various athletic groups, including wrestlers, football players, soccer players, rugby players, and cyclists (Franco & Herzog, 1987; Jacobs, Nichols, Holmes, & Buono, 1995; Mansell, Tierney, Sitler, Swanik, & Stearne, 2005; Olivier & Du Toit, 2008; Ylinen et al., 2003), no research has investigated the isotonic neck strength of these athletes nor the cervical muscle strength of any hockey players. Furthermore, no study has compared the neck strength profiles among different groups of athletes. Therefore, much research is still needed to investigate the effects of isometric and isotonic cervical strength training in athletics.

In addition to testing the neck strength of male hockey players it would be valuable for researchers to assess the neck strength of female and youth hockey players. In comparison to males, females generally have less head mass, smaller neck girths, less neck stiffness, and lower cervical strength (Mansell, Tierney, Sitler, Swanik, & Stearne, 2005). As a result, physically active females tend to experience greater head-neck segment acceleration than males when their heads are subjected to the same load (Mansell, Tierney, Sitler, Swanik, & Stearne, 2005). Therefore, female hockey players are still at an increased risk for concussion and whiplash injuries despite there being no body checking involved. By examining the cervical anthropometrics and neck strength of youth players appropriate training programs can be developed for younger athletes. Investigating appropriate cervical muscle size and strength for neck injury prevention may also be significant to the literature regarding body checking in youth hockey. Comparing the neck strength of varsity and elite players may provide further insight into the training effects of the cervical muscles and identify different areas of muscle weaknesses. In addition to hockey, future research should continue to investigate the cervical strength profiles of athletes involved in other sports, especially those associated with a high risk of neck injuries such as football and rugby. Different contact sports, or even various positions within the same sport, may require more emphasis on specific neck muscles depending on the type of injuries that most commonly occur. Testing the cervical strength of athletes from various other sports teams and of different levels of competition would also expand the generalizability of findings from this study.

According to LeSuer, McCormick, Mayhew, Wasserstein, and Arnold (1997) the Wathen (1994) equation is most accurate for predicting 1-RM values related to bench press and squat performances. It is unknown, however, if another prediction equation would be more suitable for predicting 1-RM values of the cervical muscles. It may be beneficial to compare 1-RM values predicted from different formulas. As LeSuer et al. (1997) also explained, a prediction formula specific to a particular exercise would contribute to the accuracy of predictions for that lift. Therefore, a neck specific 1-RM prediction formula would also be a valuable contribution to the literature.

Although the testing equipment and procedures of this study seemed to be effective for assessing cervical strength, many participants found the placement of the head pads awkward for flexion exercises and experienced the pads slipping during increased weight loads. If future testing is completed using the Nautilus neck machine, it is advised that participants wear a swim cap in order to minimize slipping and maximize results. Suryanarayana and Kumar (2005) reported than when comparing isometric neck strength at various degrees of flexion and extension, maximum isometric force was consistently produced in neutral neck position. In monitoring the EMG activity of neck flexors and extensors in flexed and extended positions, Lecompte, Maisetti, Guillaume, Skalli, and Portero (2007) found EMG activity decreased from extension to flexion in women only. For male participants similar muscle activation was observed within 30^0 of range of motion around the neutral position for both directions. Based on these results, the current study evaluated isometric cervical strength in neutral neck position only. It may be valuable, however, to assess isometric neck strength at various neck positions within the Nautilus machine. Furthermore, combining other muscle assessment modalities, such as EMG technology, with the Nautilus machine would be beneficial to gaining a further understanding of neck muscle functioning. Observing neck muscle activation patterns at various degrees of isometric and isotonic neck flexion and extension when using the Nautilus machine may provide valuable information regarding cervical force output.

Applications

In addition to evaluating isotonic neck strength a predictive 1-RM strength test could be used to assess cervical muscle endurance and neuromuscular fatigue of athletes. According to Armstrong, McNair, and Taylor (2008) local muscle fatigue can be an impeding factor against optimal proprioceptive performance of the cervical muscles. Muscle fatigue may, therefore, reduce the speed and force of cervical muscle contractions, which are essential to reducing the risk of serious neck injury during impact. As repetitions above 12 are suitable for programs aimed at muscle endurance, future studies can use the Nautilus neck machine for submaximal tests of higher repetitions to investigate cervical muscle endurance. Finally, predicted 1-RM data may assist trainers and coaches of various sports establish return to play criteria following head and neck injuries. Normative 1-RM values would also be useful for screening players that are involved in high-risk sports such as ice hockey, rugby, football and wrestling.

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Appendix A

Pre-Screening Assessment Form

Adapted from Yodas et al. (1992)

Participant Information

Name: ______________________________

Participant Group: _____________________

Age: __________________

Years of Training Experience: ____________

Prescreening Information

Table A1

Pre-screening Questions

Question	Y/N	Notes
Do you currently suffer from persistent neck pain?		
Are you currently taking any medications for neck pain?		
Have you ever had neck surgery?		
Have you ever had a neck injury that required medical care?		
Have you ever had any other spinal injury that required medical care?		
Have you ever been diagnosed with cervical spondylosis or osteoporosis?		

Table A2

Cervical Active Range of Motion

Neck Movement	Normal Cervical AROM (^{0})	Measured Cervical AROM (^{0})	Pain Present (Y/N)
Flexion	42-83		
Extension	60-108		
Right Lateral Flexion	30-66		
Left Lateral Flexion	30-60		
Right Rotation	59-85		
Left Rotation	52-85		

***Note.* Normal cervical active range of motion measurements are from Yodas et al. (1992)

Appendix B
Participant Information Letter

September, 2010

Dear prospective participant,

I would like to extend an invitation to participate in a research study titled "The Relationship Between Maximal Isometric and Isotonic Neck Strength of Hockey Players and Wrestlers". The study is being conducted by me, Morgan Broennle, a graduate student in the School of Kinesiology at Lakehead University, supervised by Dr. Derek Kivi. The literature suggests that strength training for the cervical muscles can reduce the risk and severity of neck injuries associated with contact sports and assist in improving athletic performance. The techniques currently used for assessing neck strength, however, are inappropriate for evaluating the types of training programs that are necessary for athletes. By participating in this study you will be providing information that can be used to develop appropriate methods of testing the neck strength of athletes in contact sport.

The primary purpose of this study is to predict participants' 1 repetition maximum (1-RM) for cervical flexion and extension using a 6 repetition maximum (6-RM) test completed to fatigue. The secondary purpose is to examine the relation between maximal isometric and predicted 1-RM measures of neck strength among three groups of participants; wrestlers, hockey players, and a healthy control group. Prior to any involvement in this study, you will be required to sign the attached consent form and Physical Activity Readiness Questionnaire (PAR-Q). You will also need to complete a pre-screening assessment, which includes an evaluation of cervical active range of motion and questions regarding previous neck injuries.

All participants are required to attend a familiarization session and two test sessions in the Exercise Physiology Laboratory (SB 1025) at the Lakehead University Fieldhouse. Each session will be scheduled 3 to 5 days apart at approximately the same time of day. The purpose of the familiarization session is to become accustomed with the testing equipment and procedures. Height, weight, and neck measurements (length and girth) will also be taken and recorded at this time. During the following two sessions you will be tested for neck strength, using two different types of testing techniques. One test protocol will require you to perform three maximal isometric efforts in neck flexion and extension. During data collection, a strain gauge load cell will be used to measure the force produced during each isometric effort. At the other test session you will complete a 6-RM test completed to fatigue for both cervical flexion and extension. The order in which the two test protocols are completed will be randomly assigned. As well, flexion and extension tests will be performed in random order at each session.

At the start of each session, you will be guided through an appropriate warm-up and neck stretching routine. This will consist of 5 minutes of light activity followed by a series of dynamic neck stretches. After testing, you will cool down by performing a set of static neck stretches. You will also be asked to keep a training/activity log recording the type and duration of any physical activity you participate in outside of the study. You must also note any pain or muscle soreness that you experience following a test session or other physical activity. This log is intended as a safety precaution, ensuring adequate muscle recovery between test sessions. Potential risks of participating in this study include, but are not limited to, minor cervical sprains and strains, and neck muscle soreness. Participation in this study is voluntary; you have the right to withdraw at any time without penalty. All information will be strictly confidential. Only the researchers will have access to the recorded data and personal information, and no identifiable characteristics will be used in the final report. Data will be stored at Lakehead University, with the faculty advisor, for a period of 5 years.

Individual results of this study will be available to all participants upon request following the completion of the study. Results may be beneficial to you as a participant as you will learn about your neck strength profile, which could be used to improve sports performance. If you have any questions please feel free to contact me, or you may contact the Lakehead University Research Ethics Board at 343-8283.

Thank you,

Morgan Broennle, MSc (c),
(807) 472-0678
mmbroenn@lakeheadu.ca

Dr. Derek Kivi, Graduate Supervisor
(807) 343-8645
dkivi@lakeheadu.ca

Appendix C
Participant Consent Form

The Relationship Between Maximal Isometric and Isotonic Neck Strength in Hockey Players and Wrestlers

1. I,____ (PLEASE PRINT), agree to participate in this study concerning cervical strength testing. I am aware that the purpose of this study is to predict the 1-RM for cervical flexion and extension using a 6-RM test completed to fatigue and to examine the relation between isometric and predicted 1-RM measures of neck strength among three groups of participants.

2. I am aware that I will need to complete a pre-screening assessment, which will include an evaluation of cervical active range of motion and questions regarding previous neck injuries. I will also be required to sign a consent form and complete a Par-Q prior to participation. I understand that if cleared for further participation I will be required to attend a familiarization session and two test sessions at the Lakehead University Fieldhouse. Each session will be scheduled 3 to 5 days apart at approximately the same time of day.

3. I understand that I will be required to perform neck flexion and neck extension exercises using both isometric and isotonic techniques. I understand that I will also complete a light warm-up and neck stretches before testing, a cool down following testing, and will need to keep a training/activity log recording the type and duration of any physical activity I participate in outside of the study. I am aware that information, including height, weight, neck girth, neck length, and years of training experience will be recorded by the study researchers.

4. I understand that participation in this study is entirely voluntary and I am able to withdraw from this study at any time without penalty. I understand that all information that I provide will remain confidential. Data will be securely stored at Lakehead University for a period of 5 years.

5. I have been informed of the tests that I am required to perform in this study and I am aware that with all physical activity and sports, some risk of injury does exist. I understand that risks in participating in this study may include, but are not limited to, cervical sprains, strains, and neck muscle soreness. I accept all of these risks by participating in this study.

Signature of Participant ____ Date ____________
Signature of Witness ____ Date ____________

Appendix D
Data Collection Charts

Identification Number: ____________________

Anthropometric Data

Table D1

Anthropometric Measurements

Height (m)	Mass (kg)	Neck Girth (cm)	Neck Length (cm)

Familiarization Data

Table D2

Isometric Familiarization for Cervical Flexion

Trial	Submaximal Peak Force (N)	RPE	Notes
1			
2			
3			

Table D3

Isometric Familiarization for Cervical Extension

Trial	Submaximal Peak Force (N)	RPE	Notes
1			
2			
3			

Table D4

Isotonic Familiarization for Cervical Flexion

Set	Weight (kg)	RPE	Notes
1 (10-12 reps @ 5% body wt)			
2 (8-10 reps @ 10% body wt)			
3 (6-8 reps @ 15% body wt)			

Table D5

Isotonic Familiarization for Cervical Extension

Set	Weight (kg)	RPE	Notes
1 (10-12 reps @ 5% body wt)			
2 (8-10 reps @ 10% body wt)			
3 (6-8 reps @ 15% body wt)			

Table D6

Estimated 6-RM Values

	Estimated 6-RM
Neck Flexion	
Neck Extension	

***Note.* Estimated 6-RM's are based on the weight used and the RPE values provided during the isotonic familiarization sets

Isometric Test Data

Table D7

Isometric Test Results for Cervical Flexion

Trial	Peak Force (N)	RPE	Notes
1			
2			
3			

Table D8

Isometric Test Results for Cervical Extension

Trial	Peak Force (N)	RPE	Notes
1			
2			
3			

Isotonic Test Data

Table D9

Isotonic Test Results for Cervical Flexion

Set	Weight (kg)	RPE	Notes (Number of repetitions completed)
Warm-up (10 reps @ 50% estimated 6-RM)			
1 (6 reps @ 70% estimated 6-RM)			
2 (3-6 reps @ 90% estimated 6-RM)			
3 (Attempted 6-RM @ 100-105% estimated 6-RM)			

Table D10

Isotonic Test Results for Cervical Extension

Set	Weight (kg)	RPE	Notes (Number of repetitions completed)
Warm-up (10 reps @ 50% estimated 6-RM)			
1 (6 reps @ 70% estimated 6-RM)			
2 (3-6 reps @ 90% estimated 6-RM)			
3 (Attempted 6-RM @ 100-105% estimated 6-RM)			

Predicted 1-RM Values

Table D10

Predicted 1-RM Values for Cervical Flexion & Extension

	Number of Repetitions Completed	Weight (kg)	Predicted 1RM **
Neck Flexion			
Neck Extension			

***Note.* Predicted 1-RM values calculated using the Wathen (1994) equation,
1-RM = $(100 \times W) / (48.8 + (53.8 \times e^{-0.075 \times R}))$.

Appendix E
PAR-Q

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of <u>any other reason</u> why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________

SIGNATURE ______________________ DATE ______________________

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority) ______________________ WITNESS ______________________

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Appendix F
Standardized Warm-up & Neck Stretches

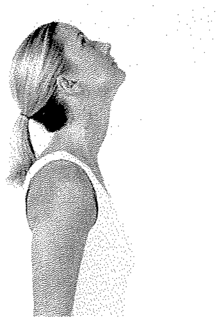
Warm-up

Perform 5 minutes of light pedaling on an exercise bike. Intensity should be set high enough to slightly elevate heart rate and increase blood flow to muscles. Participant should still be able to carry on a conversation comfortably. Perceived exertion for the warm-up should be rated at approximately 10 or 11 according to the Borg 15-Catergory Scale.

Dynamic Neck Exercises

Perform 10 to 12 repetitions of each exercise using a slow, continuous motion.

1. Neck Flexion and Extension
Bend your head forward, until your chin touches your chest and eyes look straight down at the floor. Bring your head back up to neutral position. After resting a moment bring your head back until your eyes look directly at the ceiling.



2. Right/Left Head Rotation
Rotate your head to one side until you can't turn it any farther. Bring your head back to the centre point. Rest a moment then turn your head to the opposite side.

3. Neck Retraction

Draw your head back and bring your chin down slightly. Hold retraction for 2 seconds and then return to neutral position.

4. Right/Left Lateral Neck Flexion

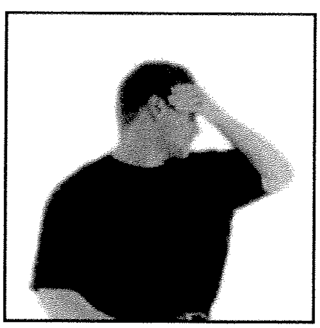
Keep your head facing forward and move your ear down toward your shoulder until you feel a stretch along the opposite side of your neck. Bring your head back to the centre. Rest a moment then move your head over to the opposite side.

Static Neck Stretches

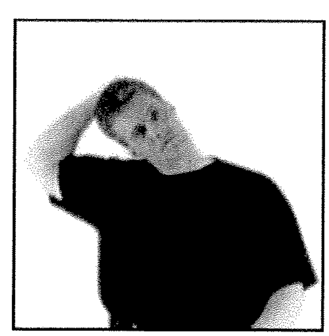
Perform each stretch 2-3 times. Hold each stretch for 15 to 20 seconds.

1. Neck Flexion and Extension
Slowly tuck your chin and allow your head to drop down towards your chest. Apply slight pressure to the back of the head with either hand to increase the stretch. You should feel a stretching sensation in the neck and back. Slowly tilt your head backwards as if looking up towards the ceiling. Apply slight pressure to the top of the head with either hand to increase the stretch.

2. Right/Left Neck Rotation
Slowly rotate your head to the side. Apply slight pressure to the side of the head to increase the stretch. You should feel a stretching sensation along the side of neck.



3. Right/Left Lateral Neck Flexion
Slowly laterally flex your head by bringing your ear to the shoulder. Apply slight pressure to the side of the head with the same side hand to increase the stretch. You should feel a stretching sensation in the opposite side of the neck.



Appendix G
Raw Anthropometric Data

Participant	Age	Yrs. of Training	Height (cm)	Mass (kg)	Weight (N)	Neck Girth (cm)	Neck Length (cm)
Controls							
C1	20	7	179	80.0	784	36	14
C2	22	10	180	95.5	935.9	40	11
C3	20	10	178	67.8	664.4	37	11
C4	23	7	164	80.3	786.9	41	9
C5	21	5	176	75	735	38	12.5
C6	21	5	185	93	911.4	39	14
C7	19	6	161.5	60	588	36	10.5
C8	24	7	170	78	764.4	38.5	11
Hockey Players							
H1	21	6	184	84.3	826.1	38	10.5
H2	21	5	174.5	76	744.8	38.5	12
H3	20	6	186.5	106.8	1046.6	41	12
H4	21	6	183	82.3	806.5	39.5	13
H5	24	10	191	96.5	945.7	40	13
H6	19	7	178.5	95	931	41	14
H7	18	5	170	76.7	751.7	37.5	10.5
H8	22	7	179.5	75	735	36.5	10
Wrestlers							
W1	19	3	187	90.2	884	38	13
W2	24	11	195	106	1038.8	44	14
W3	21	3	172	84	823.2	39.5	8
W4	18	3	175.5	86	842.8	39.5	11.5
W5	23	9	170	76.3	747.7	42	10
W6	22	9	169	57.4	562.5	37.5	11
W7	21	7	176	57	558.6	35.5	13
W8	22	10	184	91.5	896.7	43	12

Appendix H
Raw Cervical Strength Data

Participant	Maximum Isometric Flexion (N)	Maximum Isometric Flex./Body Weight	Predicted 1-RM Flexion (kg)	Predicted 1-RM Flex./Body Weight	Maximum Isometric Extension (N)	Maximum Isometric Ext./Body Weight	Predicted 1-RM Extension (kg)	Predicted 1-RM Ext./Body Weight
Controls								
C1	118.5	.51	17.2	.22	151.3	.19	23.2	.29
C2	152.8	.16	14.0	.15	266.9	.29	18.6	.20
C3	73.3	.11	13.5	.20	174.8	.26	26.2	.39
C4	140	.18	15.9	.20	183.8	.23	37.0	.46
C5	98.6	.13	15.4	.21	152.9	.21	31.9	.43
C6	102.7	.11	17.2	.19	168.5	.19	29.0	.31
C7	73	.12	15.8	.26	102	.17	23.2	.39
C8	87.5	.11	15.2	.20	83.7	.11	23.0	.30
Hockey Players								
H1	175.7	.21	16.7	.20	269.3	.33	38.4	.46
H2	141.3	.19	15.8	.21	202.1	.27	23.2	.31
H3	175.4	.17	21.1	.20	213.3	.20	32.9	.31
H4	167.6	.21	14.9	.18	185.1	.23	17.2	.29
H5	139.6	.15	19.7	.20	214.6	.23	35.5	.37
H6	275.1	.30	19.1	.20	260.1	.23	36.1	.38
H7	98.6	.13	13.6	.18	142.2	.29	31.9	.42
H8	130	.18	10.2	.14	182.1	.25	16.7	.22
Wrestlers								
W1	221.2	.25	23	.26	301.5	.34	35.5	.39
W2	193.6	.19	20	.19	281.9	.27	40.6	.38
W3	125.9	.15	19.1	.23	196.3	.23	36.6	.44
W4	105.9	.13	18.3	.21	186.1	.22	34.5	.40
W5	161.3	.22	32.7	.43	259.3	.35	43.4	.57
W6	186.9	.33	20.2	.35	273.7	.49	37.6	.66
W7	107.1	.19	21.9	.38	111.3	.20	37.7	.66
W8	231.4	.26	29	.32	310.7	.35	46	.50

Appendix I
Scatterplots for Pearson Moment Correlation

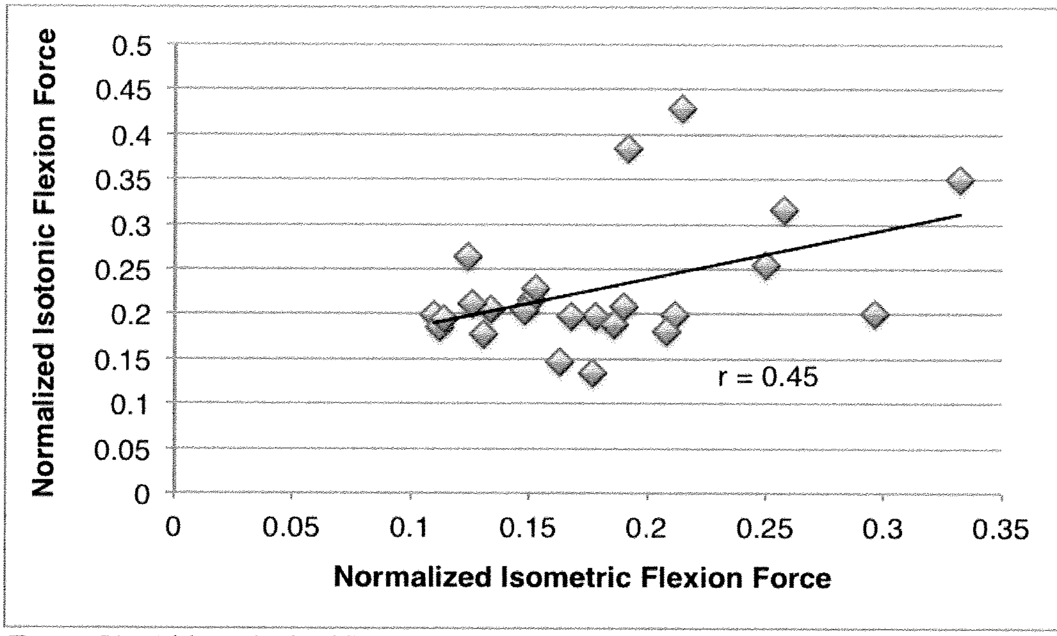


Figure I1. Although significant the linear correlation between isometric and isotonic cervical flexion force was low (r = 0.45, $p > 0.05$)

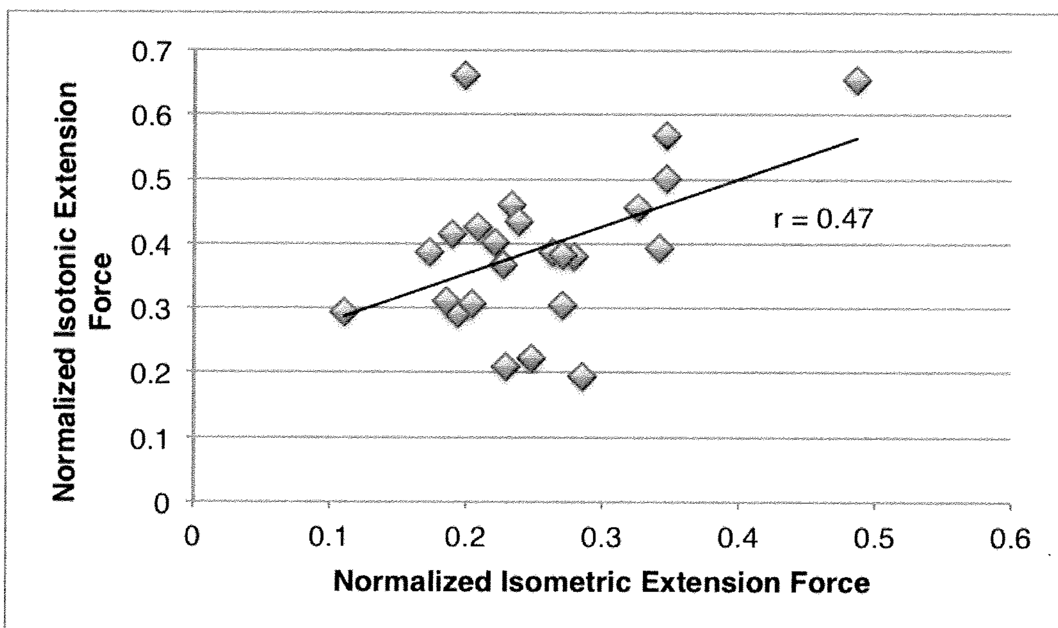


Figure I2. A low linear correlation was observed between isometric and isotonic neck extension force values (r = 0.47, $p > 0.05$).

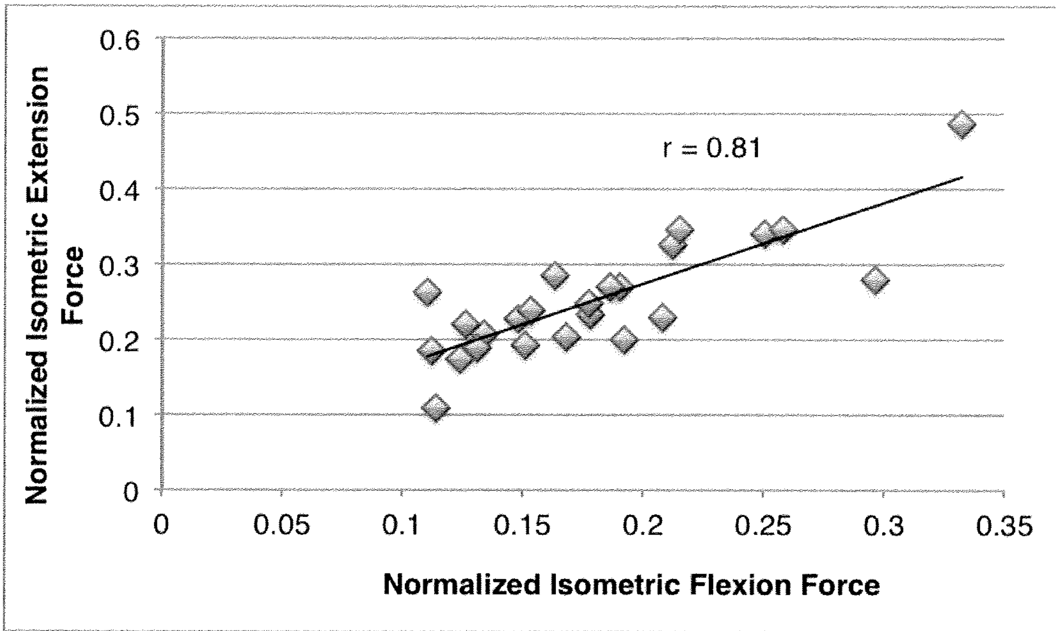


Figure 13. A strong linear correlation was shown between isometric flexion and extension force values (r = 0.81, $p > 0.01$)

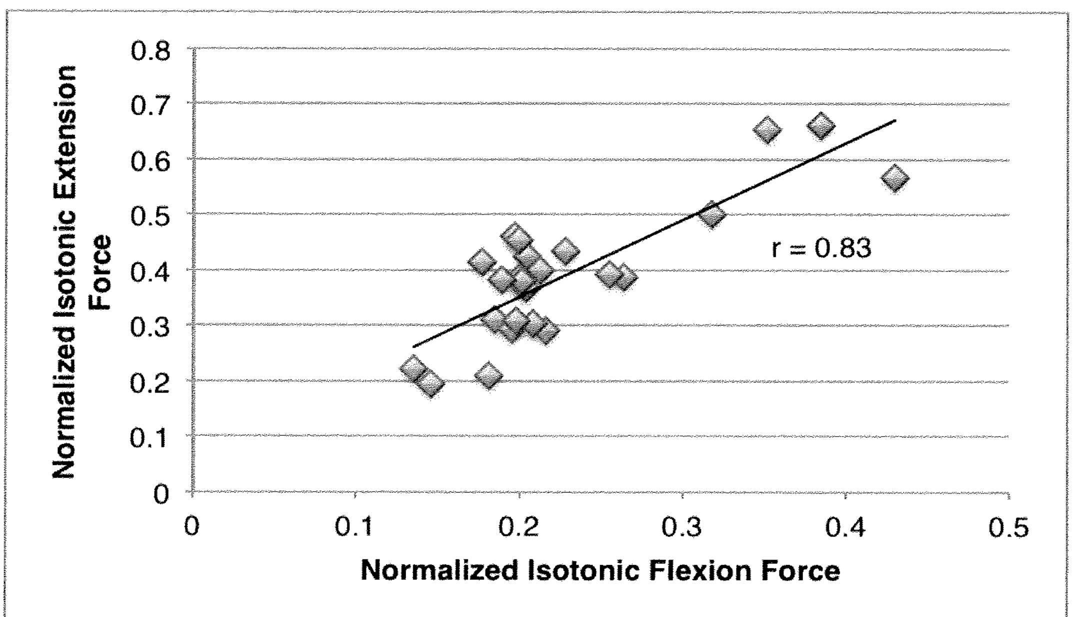


Figure 14. The strongest linear correlation occurred between isotonic flexion and extension force values (r = 0.83, $p > 0.01$)